Annual Report

Rehabilitation Research and Baseline Monitoring

White River Shale Project

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White River Shale Project

For the period

1 January 1979 to 31 December 1979

by

Staff, Institute for Land Rehabilitation

Utah State University

Logan, Utah

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I. EXECUTIVE SUMMARY

A. Perspective on year's activities.

Research during 1979 consisted mainly of monitoring existing field studies to determine the degree of stability achieved in establishment. Obviously the number of surviving plants is of continuous importance and not just at the end of one or two years. Experiments with outplanting container-grown shrubs and grass in fall vs spring have reached a good equilibrium with very few additional plants lost in 1979. This degree of stability is important. Results of an experiment at Section 6 show a dramatic benefit from reducing plant competition during the first or first and second planting year. Plant survival under the influence of dense weed competition was between 16 and 25 percent after three years. In contrast, survival where competition was removed during the first year was from 45 to 62 percent but where competition was removed for the first two years after field planting survival was between 87-89 percent.

B. Weather during 1979 was more nearly average for the oil shale tracts than many previous years. Total precipitation was 10.3 inches as compared with an average of 8-9 inches.

C. Studies discussed, even though briefly, in this report include the following:

1. Influence of plant competition control during the establishment of transplanted bare root and container-grown plants. (a) Study at section 6, (b) study at sites G-3, and G-17.
2. Effect of age and size of transplants on their survival

following field planting. (a) Older plants pruned to reduce size (b) Young transplants less than 6 months old.

3. Plant propagation method and season of planting as factors in establishment and survival of shrubs and grasses on disturbed sites.
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   c. Plant performance and survival in basins and furrows on a shale disposal pile.
   d. Mycorrhizal innoculation to increase plant growth and survival in processed oil shale.
9. Endangered species studies of Southam Canyon.

D. A number of studies are now ready for reporting in technical journals and manuscripts are planned or in preparation.

Experiments with mycorrhizae innoculation of transplants have shown that it is possible to increase survival and growth with use

of mycorrhizal cultures produced from plant/soil samples obtained from undisturbed field sites in the vicinity of the experimental area.

II. INTRODUCTION

This report of activities for 1979 combines results from research studies and baseline monitoring efforts. Our continuation of observing the results of field studies at section 6 and other research sites on the oil shale tracts has value because it provides a time dimension for judging the effectiveness of treatments and persistence of planted species under varying stress conditions. Continuing the baseline monitoring activities, even though at a reduced scale from the original 2-year intensive study of 1965-66, provides a perspective of the fluctuations in vegetation parameters over time.

Compared with previous years since 1975 the growing season of 1979 was close to average. Temperature and precipitation were not extreme and caused no significant plant responses (Table 1). Average precipitation at the section 6 study site was 10.3 inches.

Continued monitoring of some of the plots at section 6 and other sites will be valuable although no drastic changes are anticipated. Experience with PL 95/87, the surface mine control and reclamation bill of 1977, and surface mine reclamation litigation convinces us that data and the longevity of plantings and plant performance over an extended period of time can be of significant value in substantiating claims for success in rehabilitation.

Those studies that appear to hold promise for the greatest future use are; 1. Season of planting, methods of planting and type of planting material, 2. Effects of plant competition on the survival of bareroot and container grown species, 3. The oil shale disposal pile

pilot model, and 4. Plant establishment studies on a compacted oil shale disposal pile.

Table 1. Inches of precipitation recorded at Section 6 Research Site. (Rain gauge RV.7.) for the growing season October 1978 - Sept. 1979.

O	N	D	J	F	M	A	M	J	J	A	S
.59	1.11	1.27	.45	.25	2.65	.95	1.33	t	.69	.76	.25

Season total 10.30 inches

III. RESULTS OF FIELD STUDIES

The following studies were monitored in our review of field plots in June and September 1979. Some studies, such as those at Anvil Points and the research of Mycorrhizal influences on improved plant establishment were monitored more frequently than spring and fall.

A. Control of plant competition

Two studies as to the effect of annual plant competition on the survival and growth of several transplanted species were field planted in section 6 and at Drill Site G-8 in early spring of 1977. Two years of data from these studies were reported in the final report. All plants were originally grown in the greenhouse as container grown for greater uniformity. Half of the plants at the time of field planting had all soil material removed from their roots and these were planted as bare-root stock. These plants, due to their being grown in containers had a more prolific root system including many fibrous roots than those normally grown as bare-root stock. The other half were planted as container grown stock.

Plant survival taken in the spring and fall over three growing seasons comparing bare-root and container grown stock under three plant

competition levels at the Section 6 study are shown in Table 2.

The survival differences between the 2 year clean cultivation and the control treatments at the end of the third growing season are quite discernible with plant survival at the 1 year of clean cultivation lying between the two other treatments.

Annual plant competition though detrimental did not have the extreme effect on the survival of Kochia prostrata as it did on the other three species. Two years of clean cultivation was six times better than the survival of container plantings under the control treatment and 40 times better than the bare-root planting at the end of the third growing season for the three species (omitting Kochia prostrata).

Three to four growing seasons or longer may be needed to determine the full establishment of plants under these arid conditions as shown in Figure 1. Plants under normal competition appear to be stabilizing in their survival during the third year but there are only indications of this occurring under the other two treatments.

Plant growth showed various restrictions in height and plant cover where the four species were subjected to the three levels of annual plant competition as shown in Table 3.

The average plant cover of all four species at the end of the third growing season were approximately 3.5 square decimeters in the control treatment, 4.5 following 1 year clean cultivation and 7.5 following 2 years clean cultivation, or the latter having twice the growth cover of the control.

The survival and growth of the five shrubs established at site G-8 and comparing six treatments in each of two annual plant competition levels over three growing seasons are shown in Table 4, 5 and 6. No

Table 2 Influence of other plant competition on the survival of four plant species and in comparing two methods of planting - bare-root and container-grown transplants. Data shows survival at six observation dates and the average of all four species at the beginning and end of the third growing season.

Species	Observation Date	Control		1 yr clean		2 yr clean	
		Bare-root	Container	Bare-root	Container	Bare-root	Container
		%	%	%	%	%	%
Fourwing saltbush	1977 - Spring	94	100	94	88	94	94
	- Fall	56	88	94	88	94	94
	1978 - Spring	50	88	94	88	94	94
	- Fall	6	38	81	81	94	88
	1979 - Spring	6	13	81	75	94	88
	- Fall	0	13	81	75	94	81
Winterfat	1977 - Spring	100	100	100	100	100	94
	- Fall	94	94	75	100	100	94
	1978 - Spring	75	94	69	100	100	94
	- Fall	56	88	56	88	94	94
	1979 - Spring	6	13	19	50	81	88
	- Fall	6	13	19	44	81	88
Kochia prostrata	1977 - Spring	100	100	100	100	100	100
	- Fall	100	100	100	100	100	100
	1978 - Spring	100	100	100	100	100	100
	- Fall	88	88	88	94	100	100
	1979 - Spring	63	63	56	94	100	100
	- Fall	63	63	56	94	100	100
Russian wildrye grass	1977 - Spring	94	94	88	94	94	100
	- Fall	8	50	75	94	94	94
	1978 - Spring	8	50	75	94	81	94
	- Fall	0	13	31	63	81	81
	1979 - Spring	0	13	31	63	81	81
	- Fall	0	13	19	38	81	75
Average - 4 species	1979 - Spring	19	25	47	70	89	89
	- Fall	17	25	44	63	89	86

Date of field transplanting - April 5, 1977 Experiment A 14

The competition treatments are: (1) control where weedy plants are allowed to grow; (2) one-year clean cultivation; and (3) two-year clean cultivation.

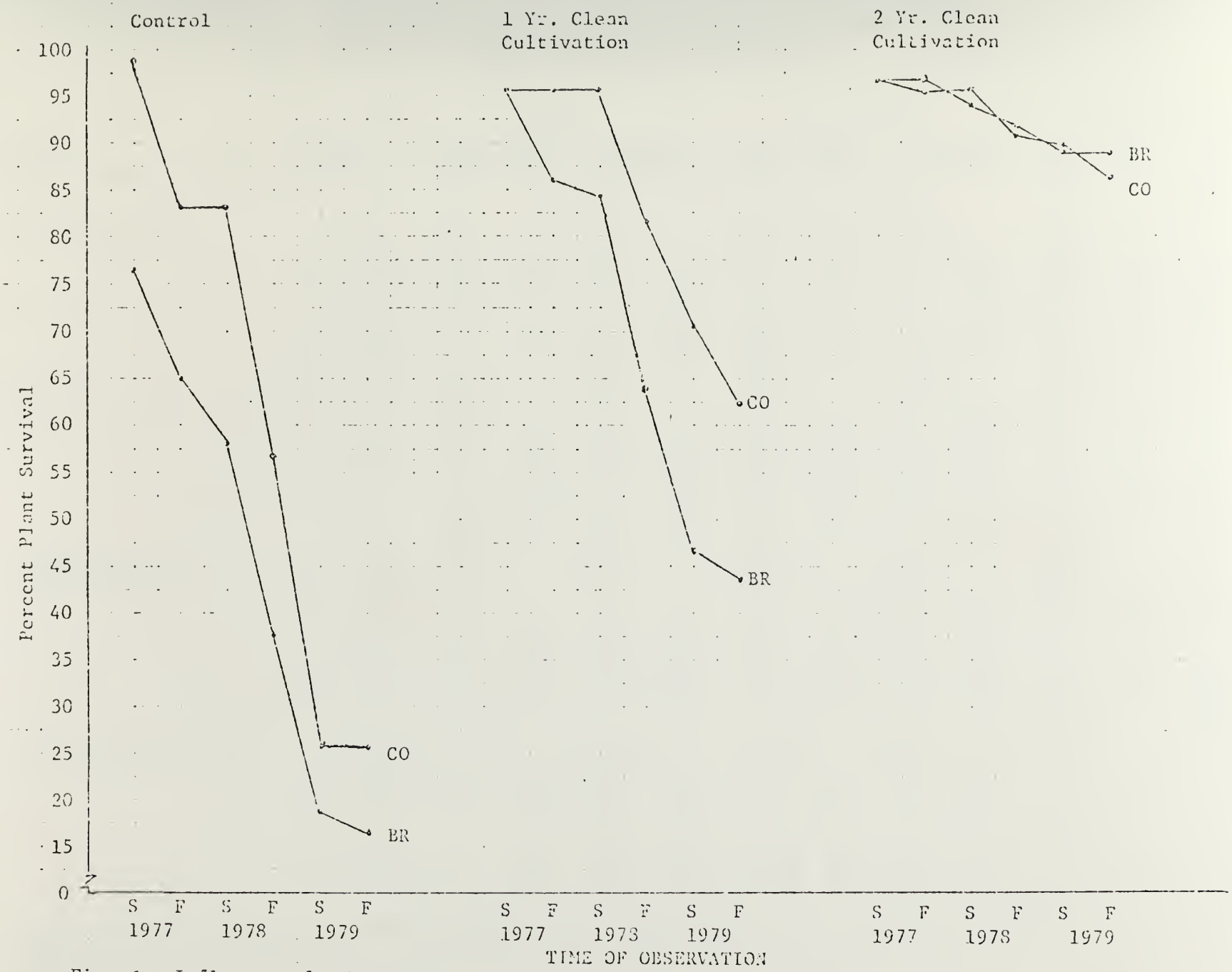


Fig. 1. Influence of other plant competition on the average survival of four plant species over three growing seasons. Compared are two methods of planting - bare-root (BR) and container (CO) planted stock growing under three levels of annual plant competition. Date of field planting was April 5, 1977.

Table 3. Influence of other plant competition on the height and plant cover of four plant species and in comparing two methods of planting bare-root and container-grown transplants over a three-year period.

Species	Observation Date	Control				1 yr clean				2 yr clean			
		Bare-root		Container		Bare-root		Container		Bare-root		Container	
		cm	dm^2	cm	dm^2	cm	dm^2	cm	dm^2	cm	dm^2	cm	dm^2
Fourwing saltbush	1977-Spring	7.1		8.3		9.2		8.1		9.4		8.4	
	-Fall	9.1		8.4		24.3		25.5		22.6		22.9	
	1978-Spring	14.3	0.7	13.2	0.7	31.8	5.0	33.6	7.2	34.6	6.4	33.2	6.7
	-Fall	10.0	0.5	8.8	0.3	31.2	4.7	33.4	6.6	44.0	8.1	37.5	10.2
	1979-Spring	2.0	0.1	16.5	0.6	28.5	3.3	31.0	4.9	34.3	7.4	32.2	8.0
	- Fall	0	0	32.0	1.0	40.8	4.5	48.3	7.8	48.7	8.5	47.4	10.4
Winterfat	1977-Spring	11.9		13.8		9.6		12.6		9.9		11.8	
	-Fall	13.3		13.9		18.4		20.7		17.4		19.3	
	1978-Spring	18.8	0.8	19.9	0.8	27.8	1.6	28.7	2.7	27.7	2.5	29.6	3.0
	-Fall	11.7	0.6	15.8	0.3	19.8	1.8	24.8	2.5	37.4	3.1	37.5	4.3
	1979-Spring	30.0	2.0	23.0	0.8	16.3	0.7	21.0	1.5	31.3	3.5	32.6	4.4
	-Fall	40.0	4.0	35.5	3.0	23.0	0.9	25.5	2.0	37.7	4.2	41.0	4.8
Kochia prostrata	1977-Spring	17.3		18.0		17.3		20.9		16.8		24.2	
	-Fall	22.9		23.9		39.3		39.3		36.6		42.9	
	1978-Spring	28.4	2.2	29.7	3.6	29.8	5.3	33.8	6.5	27.5	5.4	35.0	6.7
	-Fall	24.3	0.6	30.5	2.7	24.8	3.8	33.8	6.3	40.7	10.8	47.7	15.7
	1979-Spring	26.9	3.0	31.0	3.6	31.0	6.6	33.1	7.0	32.4	9.4	35.5	9.8
	-Fall	52.8	8.4	54.3	10.9	45.3	10.7	48.0	10.4	47.0	13.3	49.3	14.3
Russian wildrye grass	1977-Spring	4.9		11.8		4.7		9.1		5.3		6.9	
	-Fall	0		2.0		8.6		9.9		6.5		6.9	
	1978-Spring	46.0	0.5	22.8	0.9	51.1	1.5	48.0	1.5	47.9	2.3	42.5	1.6
	-Fall	0	0	0	0	0	0	1.0	0.1	1.0	0.2	1.6	0.2
	1979-Spring	0	0	26.0	0.8	15.8	0.4	24.3	1.8	30.8	4.1	26.3	3.1
	-Fall	0	0	11.0	0.8	5.5	0.2	16.0	1.5	23.5	3.0	15.7	2.1

Date of field transplanting - April 5, 1977 Exp. A14

The competition treatments are: (1) control where weedy plants are allowed to grow; (2) one-year clean cultivation; and (3) two-year clean cultivation.

Table 4. Survival of five shrub species in which six treatments are exposed to two levels of weedy plant competition - control and clean cultivation. Data shows survival at two observation times over a three-year period.

Species and Time of Observation	Control - Not Cultivated						Clean Cultivation					
	1	2	3	4	5	6	1	2	3	4	5	6
	%	%	%	%	%	%	%	%	%	%	%	%
Greasewood												
1977 - Spring	100	100	100	100	100	100	100	100	100	100	100	100
Fall	75	50	25	75	100	75	75	100	100	75	50	75
1978 - Spring	50	50	25	75	75	75	75	100	100	75	50	75
Fall	50	50	25	50	75	50	75	100	100	75	50	75
1979 - Spring	50	25	25	25	75	50	75	100	100	75	50	75
Fall	50	25	25	25	50	50	75	100	100	75	50	75
Fourwing saltbush												
1977 - Spring	100	100	100	100	100	100	75	100	100	100	100	100
Fall	50	75	75	100	75	75	75	75	100	75	100	75
1978 - Spring	25	75	75	100	25	50	50	75	75	75	50	25
Fall	25	25	0	75	25	50	50	75	75	75	50	25
1979 - Spring	0	25	0	50	25	25	50	75	75	50	50	25
Fall	0	25	0	50	25	25	50	75	75	25	50	25
Shadscale saltbush												
1977 - Spring	75	75	50	75	50	100	75	100	100	100	100	75
Fall	75	75	25	75	25	100	25	100	100	100	100	75
1978 - Spring	75	50	25	75	25	75	25	100	100	100	100	75
Fall	75	25	0	25	0	75	25	100	100	100	100	75
1979 - Spring	75	25	0	25	0	50	25	100	100	100	100	75
Fall	75	25	0	25	0	50	25	100	100	100	100	75
Gardner saltbush												
1977 - Spring	100	50	0	50	100	100	75	100	100	100	100	100
Fall	75	25	0	50	75	100	75	100	75	50	100	100
1978 - Spring	50	25	0	50	50	50	75	100	25	50	100	75
Fall	50	25	0	50	25	50	75	100	25	50	100	75
1979 - Spring	50	0	0	50	25	0	75	100	25	50	100	75
Fall	50	0	0	50	25	0	75	100	25	50	100	75
Kochia												
1977 - Spring	100	100	100	100	100	100	100	100	100	75	100	100
Fall	100	100	100	100	100	75	100	100	100	75	100	75
1978 - Spring	100	100	100	100	100	75	100	75	100	50	100	75
Fall	100	100	100	100	100	75	100	75	100	50	100	75
1979 - Spring	100	100	100	100	100	75	100	75	100	50	100	75
Fall	100	100	100	100	100	75	100	50	100	50	100	75
Average of 5 species												
1979 - Spring	55	35	25	50	45	40	65	90	80	65	80	65
Fall	55	35	25	50	40	40	65	90	80	60	80	65

Experiment A-13

Treatments:

1. Bare-root stock, control
2. Bare-root plus water
3. Bare-root plus water plus fertility
4. Container stock, control
5. Container-grown stock plus water
6. Container-grown stock plus water plus fertility.

Table 5. Heignt of five shrub species in which six treatments are exposed to two levels of weedy plant competition - control and clean cultivation. Data shows height at two observation times over a three-year period.

Species and Time of Observation	Control - Not Cultivated						Clean Cultivation					
	1	2	3	4	5	6	1	2	3	4	5	6
	cm	cm	cm	cm	cm	cm	cm	cm	cm	cm	cm	cm
Greasewood												
1977 - Spring	15	16	13	12	15	14	18	14	14	10	13	11
Fall	10	15	24	12	14	9	13	11	16	10	11	11
1978 - Spring	18	15	28	17	19	13	19	17	24	18	19	21
Fall	13	16	20	10	5	11	22	19	28	21	25	24
1979 - Spring	11	12	15	17	14	15	31	20	31	16	28	32
Fall	27	14	18	40	17	17	37	24	40	25	31	33
Fourwing saltbush												
1977 - Spring	6	7	9	7	11	9	5	9	7	9	11	11
Fall	8	5	11	7	13	8	8	15	9	10	11	10
1978 - Spring	12	6	12	10	18	15	26	19	28	10	19	30
Fall	11	7	0	10	19	7	49	37	35	13	24	38
1979 - Spring	0	12	0	13	13	6	37	34	34	21	36	34
Fall	0	24	0	40	13	10	52	42	47	38	42	50
Shadscale saltbush												
1977 - Spring	6	6	10	4	4	11	7	9	12	7	8	13
Fall	6	5	9	4	4	9	13	9	11	7	7	10
1978 - Spring	10	11	21	10	15	20	22	19	20	20	17	23
Fall	10	9	0	11	0	19	20	17	19	19	17	20
1979 - Spring	19	13	0	14	0	21	34	26	27	27	27	31
Fall	21	14	0	18	0	23	32	28	33	30	31	35
Cuneate saltbush												
1977 - Spring	4	3	0	3	6	7	4	5	5	4	6	7
Fall	4	4	0	5	6	5	4	4	3	5	5	7
1978 - Spring	9	11	0	11	13	11	19	14	11	17	14	26
Fall	9	10	0	9	13	9	16	16	12	17	15	26
1979 - Spring	13	0	0	11	16	0	24	23	20	26	18	31
Fall	15	0	0	20	16	0	26	24	22	26	23	32
Kochia												
1977 - Spring	13	16	23	21	23	27	19	15	26	16	21	22
Fall	21	23	25	25	26	31	23	25	30	24	26	23
1978 - Spring	26	27	25	30	35	36	40	27	38	36	31	38
Fall	32	25	17	37	23	20	56	38	51	47	39	50
1979 - Spring	29	24	19	27	30	25	35	30	31	34	25	35
Fall	33	39	26	44	37	33	50	43	41	43	36	46
Average of 5 species												
1979 - Spring	18	15	17	16	18	17	32	27	29	25	27	33
Fall	24	23	22	32	21	21	39	32	37	32	33	40

Treatments:

Experiment A-13

1. Bare-root stock, control
2. Bare-root stock plus water
3. Bare-root stock plus water plus fertility
4. Container-grown stock, control
5. Container-grown stock plus water
6. Container-grown stock plus water plus fertility

Table 6. Growth expressed as plant cover of five shrub species in which six treatments are exposed to two levels of weedy plant competition - control and clean cultivation. Data shows plant cover in square decimeters at two observation periods for 1978 and 1979.

Species and Time of Observation	Control - Not Cultivated						Clean Cultivation					
	1	2	3	4	5	6	1	2	3	4	5	6
	dm^2	dm^2	dm^2	dm^2	dm^2	dm^2	dm^2	dm^2	dm^2	dm^2	dm^2	dm^2
Greasewood												
1978 - Spring	1.63	0.80	1.00	1.33	1.50	1.42	2.08	1.94	3.13	1.50	2.13	2.75
Fall	0.70	0.60	0.50	0.60	0.60	0.90	3.30	2.70	5.40	1.80	3.10	4.00
1979 - Spring	1.25	1.00	1.00	2.50	1.67	2.50	7.33	5.75	10.00	4.67	4.75	8.33
Fall	5.25	0.50	1.00	8.00	1.00	2.50	7.50	4.25	7.25	5.00	2.50	5.67
Fourwing saltbush												
1978 - Spring	0.50	0.50	0.70	0.65	1.50	1.13	4.00	2.03	4.17	0.23	1.63	2.00
Fall	0.20	0.10	0	0.50	0.50	0.70	9.00	3.40	6.70	0.20	3.30	4.00
1979 - Spring	0	0.25	0	2.25	4.00	0.50	12.50	6.67	8.33	1.63	6.00	10.00
Fall	0	1.00	0	3.50	0.50	0.50	18.00	8.67	12.00	3.00	7.50	15.00
Shadscale saltbush												
1978 - Spring	1.20	1.00	4.00	0.75	2.00	5.08	5.75	2.96	7.63	4.50	2.44	5.37
Fall	1.20	1.00	0	0.50	0	5.00	6.70	3.80	7.70	5.90	3.00	7.50
1979 - Spring	3.83	2.50	0	2.00	0	6.00	16.00	9.00	12.50	12.50	8.25	14.67
Fall	5.67	2.50	0	3.00	0	6.00	15.00	10.75	14.00	13.75	10.00	18.67
Cuneate saltbush												
1978 - Spring	0.63	0.75	0	0.63	2.38	1.08	1.92	1.31	0.75	1.48	1.56	6.17
Fall	0.60	0.70	0	0.60	3.70	1.00	2.80	2.30	1.10	1.70	2.50	9.30
1979 - Spring	1.25	0	0	0.75	2.00	0	6.33	5.50	5.00	5.00	4.38	14.33
Fall	2.25	0	0	2.00	4.00	0	7.00	6.75	6.00	5.50	4.63	15.00
Kochia												
1978 - Spring	1.00	2.13	2.81	3.31	2.19	7.30	5.65	2.75	6.38	4.00	3.50	3.83
Fall	0.80	1.90	2.40	4.10	2.10	6.60	8.60	5.70	12.60	8.90	5.40	10.70
1979 - Spring	1.63	2.88	2.31	4.00	3.75	6.17	8.50	6.00	8.00	7.00	4.88	7.33
Fall	2.50	6.75	3.63	8.50	3.75	6.33	16.75	12.00	15.25	11.50	7.25	13.33
Average of 5 species												
1979 - Spring	1.99	1.66	1.65	2.30	2.85	3.79	10.13	6.58	8.77	6.16	5.65	10.93
Fall	3.92	2.69	2.31	5.00	2.30	3.83	9.85	8.48	10.90	7.25	6.38	13.53

Experiment A-13

Treatments:

1. Bare-root stock, control
2. Bare-root stock plus water
3. Bare-root stock plus water plus fertility
4. Container stock, control
5. Container stock, plus water
6. Container stock plus water plus fertility

differences were observed in survival between the six treatments, but between the levels of competition survival was much higher under clean cultivation. Similar observations were noticed in plant growth. This is shown more clearly in Table 7. There are variations between species as to the effect of other plant competition on plant survival and growth. Again as in the Section 6 study, Kochia prostrata survives about as well under competition as where it is removed, but growth cover is influenced greatly by competition. In averaging all five species at the end of the third growing season plant survival was 72 percent under clean cultivation and only 41 percent where there was plant competition. In comparing plant survival of the four species omitting Kochia prostrata, plant survival was 70 percent under clean cultivation and only 27 percent under normal competition. Plants under clean cultivation had three times the growth cover as those growing with plant competition as shown in Table 7 at the end of three growing seasons.

In this study plants under two years of clean cultivation appeared to be fairly well stabilized in their establishment. Those under normal competition did not show this initial survival stability until the third year following field planting as shown in Figure 2.

B. Effect of plant age and pruning levels on fourwing saltbush survival

Two uniform experiments to evaluate the effect of plant age and vegetative pruning on the survival of fourwing saltbush grown as bareroot stock were field planted in the spring of 1978 at two locations. These were at Section 6 near Bonanza, Utah planted April 6, 1978 and on the Nephi Field Station, planted April 12, 1978. Plants of one, two and three year old field grown bare-root stock were compared for survival.

Table 7. Influence of weedy plant competition on the survival and growth expressed in height and plant cover on five shrubs. Data is the averages from six treatments and four replications at six observation periods over three years.

Species	Observation Date	Survival		Height		Plant Cover	
		Control	Clean Cultivation	Control	Clean Cultivation	Control	Clean Cultivation
		%	%	cm	cm	dm^2	dm^2
Greasewood	1977-Spring	100	100	14	13		
	-Fall	67	79	14	12		
	1978-Spring	58	79	18	20	1.28	2.25
	-Fall	50	79	13	23	0.65	3.38
	1979-Spring	42	79	14	26	1.65	6.81
	-Fall	37	79	22	32	3.04	5.36
Fourwing saltbush	1977-Spring	100	96	8	9		
	-Fall	75	83	9	11		
	1978-Spring	58	58	12	22	0.83	2.34
	-Fall	33	58	9	33	0.40	4.43
	1979-Spring	21	54	11	33	1.75	7.52
	-Fall	21	50	22	45	1.37	10.69
Shadscale saltbush	1977-Spring	71	92	7	9		
	-Fall	63	83	6	10		
	1978-Spring	54	83	15	20	2.34	4.77
	-Fall	33	83	12	19	1.92	5.77
	1979-Spring	29	83	17	29	3.58	12.15
	-Fall	29	83	19	32	4.29	13.69
Cuneate saltbush	1977-Spring	67	96	4	5		
	-Fall	54	83	4	5		
	1978-Spring	37	71	11	17	1.09	2.20
	-Fall	33	71	10	17	1.32	3.28
	1979-Spring	21	71	13	24	1.33	6.76
	-Fall	21	71	17	26	2.75	7.48
Kochia prostrata	1977-Spring	100	96	21	20		
	-Fall	96	92	25	25		
	1978-Spring	96	83	30	35	3.12	4.35
	-Fall	96	83	26	47	2.98	6.00
	1979-Spring	96	83	26	32	3.46	6.95
	-Fall	96	79	35	43	5.24	12.68
Average of 5 species	1979-Spring	42	74	16	29	2.35	8.04
	-Fall	41	72	23	35	3.34	9.98

Date of field transplanting - March 31, 1977 Exp. A13

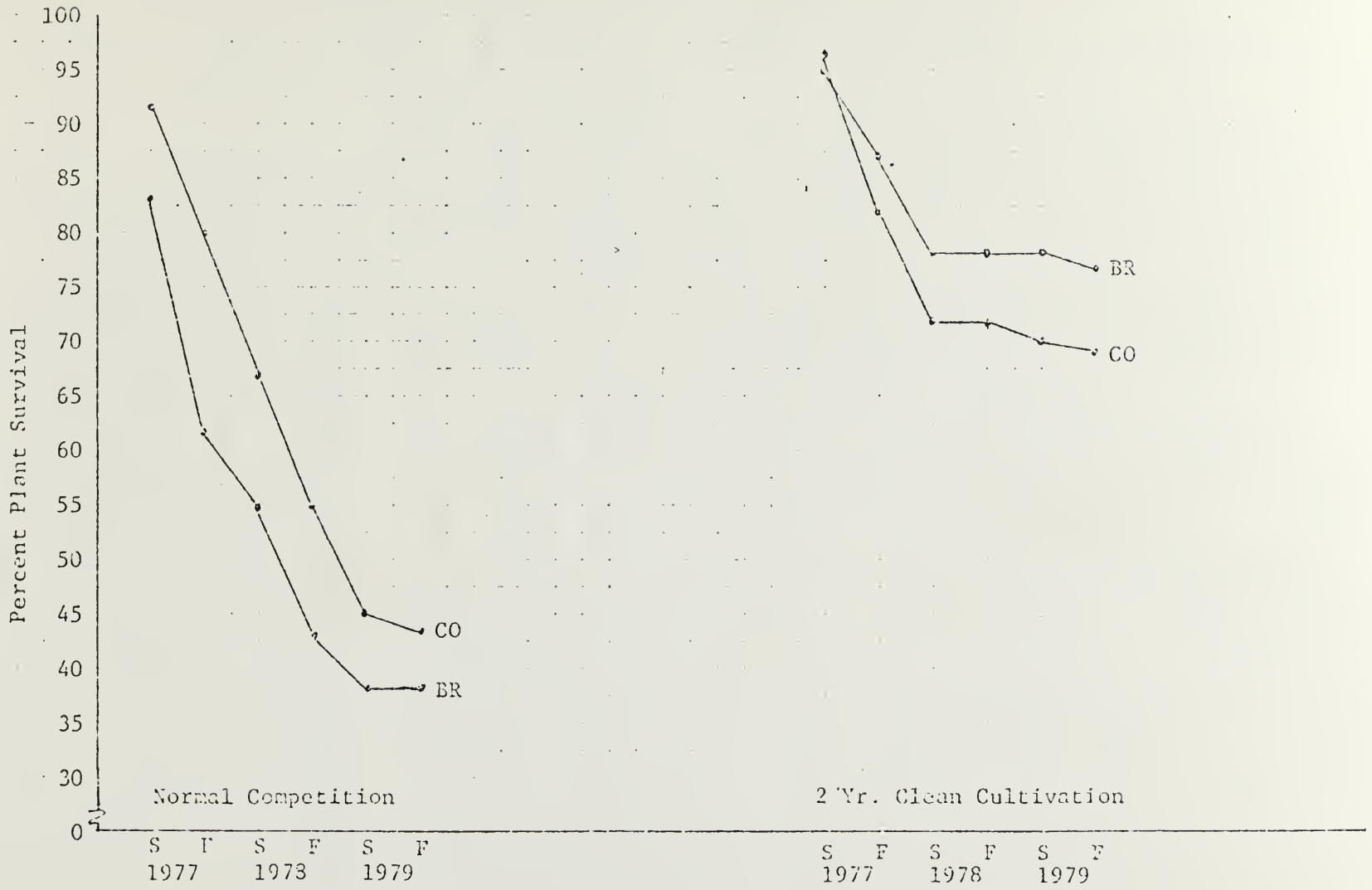


Fig. 2. Average survival of five shrub species when comparing two methods of planting - bare-root (BR) and container (CO) grown stock when subjected to two levels of plant competition - normal and clean cultivation over three growing seasons. Date of field planting was March 31, 1977.

The three levels of pruning for comparison were, unpruned (control), lightly pruned (leaving half the top biomass) and heavily pruned (leaving the stumps with only 1 to 3 inches of stems above ground depending on plant age). Survival data for two observation periods - spring and fall - over two growing seasons are shown in Table 8. One year old stock, regardless of the level of pruning, was better than two or three year old planting stock. There is little difference between survival of two and three year old plants providing they are pruned and those heavily pruned show slightly better survival and growth than those lightly pruned though not significant.

The second study on plant age as a factor in field survival dealt with relatively young planting materials.

Seedlings and rooted-stem-cuttings of fourwing and cuneate saltbushes were grown in one-quart milk cartons for 8, 16, and 24 weeks before field planting. The last 4 weeks before field planting, plants were placed outside of the greenhouse for hardening. All plants were transplanted June 13, 1978. After planting, each plant was irrigated with three liters of water. Plants were again irrigated with two liters on June 21, 1978.

A completely randomized statistical design was employed with three variables; age of plant, propagation method and species. Each treatment was replicated at least three times.

Plant survival was recorded on September 7, 1979.

Overall plant survival among the three time groups was not consistent (Table 8a). Plant survival for 8 weeks and 24 weeks was 95 and 93 percent. Survival for the 16 weeks was 85 percent. Apparently plants can be planted as young as 8 weeks and still have good survival.

Table 8. Survival of Fourwing saltbush bare-root transplants at two locations when comparing plant age and pruning variabilities. Average of 4 replications and four plants per replication.

Plant Age Years	Pruning Treatment	Bonanza (Sect 6) 1978 June	Bonanza (Sect 6) 1978 Sept	Bonanza (Sect 6) 1979 June	Bonanza (Sect 6) 1979 Sept	Nephi Field Station 1978 June	Nephi Field Station 1978 Sept	Nephi Field Station 1979 June	Nephi Field Station 1979 Sept	Average Sept 1979 Data Both Locations
		%	%	%	%	%	%	%	%	%
One	Control	100	94	94	94	100	100	88	88	91
Two	Control	69	69	63	63	69	69	69	69	66
Three	Control	81	81	63	63	38	38	38	38	50
One	Light	100	100	94	94	100	100	100	100	97
Two	Light	75	75	69	69	69	69	69	69	69
Three	Light	88	88	81	81	75	75	75	75	78
One	Heavy	100	100	94	94	100	100	100	100	97
Two	Heavy	100	100	94	88	56	56	50	50	69
Three	Heavy	94	88	88	88	75	75	75	75	81
Comparing the average of each plant age (including the three treatments)										
One		100	98	94	94	100	100	96	96	95
Two		81	81	75	73	65	65	63	63	68
Three		88	85	77	77	63	63	63	63	70
Comparing the average of two and three year old plants for each pruning treatment										
Two & 3 yr Control		75	75	63	63	53	53	53	53	58
Two & 3 yr Light		81	81	75	75	72	72	72	72	73
Two & 3 yr Heavy		97	94	91	88	66	66	63	63	75

Seedling survival was slightly greater than rooted stem cuttings. Seedling survival was 94 percent while stem cutting survival was 89 percent. This result is consistent with other studies conducted at the revegetation study site.

Fourwing saltbush survival was greater then cuneate saltbush. The 16 week old cuttings of cuneate saltbush was poor. This reduced the overall survival for cuneate saltbush.

Table 8a. Influence of plant age on survival after outplanting for fourwing saltbush and cuneate saltbush seedlings and rooted stem cuttings. Survival was measured 15 months after outplanting.

Species Propagation	Age of Plant Materials at Time of Outplanting (weeks)			
	8	16	24	$\bar{X}$
Fourwing saltbush				
seedlings	90	90	90	90
cuttings	100	100	100	100
Cuneate saltbush				
seedlings	100	100	90	97
cuttings	90	50	90	77
$\bar{X}$	95	85	93	

C. Plant survival and growth comparing season and planting methods of shrubs and grass

These studies, established at drill hole sites G-3, G-17 and at Section 6 were included in the final report for the first three growing seasons. Tables 9 thru 15 are a continuation of earlier survival and growth since field planting through the 1979 (fourth) growing season.

The continual survival data over the four year period for each of the nine shrub species at three locations including season and method

Table 9. Survival comparison in transplanting nine shrub species using two methods - bare-root and container-grown stock - at three locations and at two seasons of planting - Fall 1975 and Spring 1976. Observations for comparison are shown for spring and fall survival over a four-year period. Data are averages from three treatments and from four replications at each location. Data shows percent survival, 2, 5, 14, 17, 26, 29, 38, and 41 months following the final planting.

Species and Treatment		Drill Hole G-3								Drill Hole G-17								Section 6							
		1976		1977		1978		1979		1976		1977		1978		1979		1976		1977		1978		1979	
		June	Oct	June	Sept	June	Sept	June	Sept	June	Oct	June	Sept	June	Sept	June	Sept	June	Oct	June	Sept	June	Sept	June	Sept
		%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%
Greasewood	FBR	100	92	92	92	92	92	92	92	33	33	33	33	33	33	33	33	50	42	42	33	33	33	33	33
	SBR	75	75	75	75	75	75	75	75	83	83	83	83	83	58	50	50	92	33	25	25	25	25	25	25
	FCO	100	100	100	100	100	100	100	100	92	92	92	83	83	83	83	83	100	83	75	75	75	75	67	67
	SCO	100	100	100	100	100	100	100	100	83	83	83	83	83	83	83	83	100	67	67	58	58	58	58	58
Fourwing saltbush	FBR	33	33	17	17	17	17	17	17	33	33	33	33	25	25	25	25	0	0	0	0	0	0	0	0
	SBR	100	100	92	83	83	83	83	83	100	100	75	75	75	75	75	75	100	100	100	100	100	100	100	100
	FCO	67	67	67	67	67	67	67	67	75	67	67	58	58	58	58	58	86	58	58	58	58	58	50	50
	SCO	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	92	92	92	92	92	92	92
Shadscale saltbush	FBR	67	50	25	9	0	0	0	0	83	67	58	58	50	42	42	42	83	83	83	83	83	83	83	83
	SBR	100	50	17	17	8	8	8	8	100	100	83	83	67	58	58	58	100	100	100	100	100	100	100	100
	FCO	83	58	33	25	0	0	0	0	83	83	75	75	75	75	67	67	100	92	83	75	75	67	67	67
	SCO	100	58	58	42	25	25	25	25	83	83	67	67	67	67	42	42	100	92	92	92	92	83	83	83
Cuneate saltbush	FBR	75	50	17	9	0	0	0	0	83	67	67	67	50	42	42	42	75	58	58	58	58	58	58	58
	SBR	92	42	25	17	0	0	0	0	100	100	100	100	100	100	75	75	92	92	83	83	75	75	50	50
	FCO	75	50	25	9	0	0	0	0	75	67	67	67	67	67	58	58	83	58	58	58	50	50	33	33
	SCO	92	50	0	0	0	0	0	0	100	92	83	75	75	75	75	67	100	92	92	92	92	92	75	67
Winterfat	FBR	58	50	42	42	42	42	42	42	50	50	50	50	50	25	25	25	75	75	58	58	58	50	50	50
	SBR	83	75	75	75	67	67	58	58	100	100	92	92	92	83	83	83	83	75	50	50	42	42	33	33
	FCO	100	83	75	75	75	75	58	58	75	75	67	67	67	67	67	67	83	67	8	8	8	8	8	8
	SCO	100	100	92	92	83	83	83	83	83	83	75	75	75	75	75	75	100	100	100	100	92	92	58	58
Greenes rabbitbrush	FBR	92	92	92	75	75	58	58	58	75	67	50	50	50	50	50	50	75	50	25	0	0	0	0	0
	SBR	100	100	100	100	100	83	67	67	100	83	75	75	75	75	75	75	83	42	0	0	0	0	0	0
	FCO	75	75	75	67	67	67	42	42	100	100	100	100	83	83	83	83	67	25	25	0	0	0	0	0
	SCO	100	100	100	83	75	75	75	75	100	100	100	100	100	100	100	100	100	8	0	0	0	0	0	0
Black sagebrush	FBR	92	92	92	92	92	75	75	75	100	92	83	83	83	83	83	83	100	50	0	0	0	0	0	0
	SBR	100	100	100	92	92	83	67	67	92	92	92	92	92	83	83	75	100	58	8	0	0	0	0	0
	FCO	83	83	83	83	83	83	83	83	100	100	100	100	100	100	100	100	100	67	25	25	17	8	0	0
	SCO	100	92	92	92	92	92	83	83	100	100	92	92	92	92	92	92	100	25	0	0	0	0	0	0
Big sagebrush	FBR	67	67	67	67	67	67	67	67	100	83	83	83	83	67	67	67	83	75	67	58	50	50	25	25
	SBR	100	100	100	100	100	100	83	83	100	100	100	100	100	92	92	92	50	17	17	8	8	8	8	8
	FCO	100	100	100	100	100	100	83	83	100	100	100	100	100	100	100	100	92	92	83	83	58	50	33	33
	SCO	100	100	83	83	83	83	75	75	100	100	92	92	92	83	83	83	92	50	8	8	0	0	0	0
Spreading rabbitbrush	FBR	92	83	83	83	83	67	50	42	83	58	58	58	58	42	25	25	83	75	67	8	8	0	0	0
	SBR	92	75	50	8	8	8	0	0	100	75	67	50	50	42	25	25	100	75	75	0	0	0	0	0
	FCO	100	92	67	58	58	42	17	17	50	50	50	50	50	50	25	25	100	100	92	8	8	0	0	0
	SCO	100	83	75	42	42	33	17	17	100	92	83	75	75	67	58	58	92	58	42	0	0	0	0	0
Season of Planting & Propagation Method	FBR	75	68	59	54	52	46	45	44	71	61	57	57	54	45	44	44	69	56	44	33	32	30	28	28
	SBR	94	80	70	63	59	56	49	49	97	93	85	83	82	74	68	68	89	66	51	41	39	39	35	35
	FCO	87	79	69	65	61	59	50	50	83	82	80	78	76	76	71	71	90	71	56	43	39	35	29	29
	SCO	99	87	78	70	67	66	62	62	94	93	86	84	84	82	79	78	98	65	55	49	47	46	41	40
Season of Planting	FBR+CO	81	73	64	60	57	53	47	47	77	71	69	68	65	61	57	57	80	64	50	38	36	33	28	28
	SBR+CO	96	83	74	67	63	61	56	56	96	93	86	84	83	78	74	73	94	65	53	45	43	43	38	37
Propagation Method	BR	84	74	65	60	56	51	47	46	84	77	71	70	68	60	56	56	79	61	48	37	36	35	31	31
	CO	93	83	74	68	64	63	56	56	89	87	83	81	80	79	75	75	94	68	56	46	43	41	35	34

Date of seeding: Fall - November 13-14, 1975
Spring - March 23, 1976

Table 10. Field survival of nine shrub species following three and four years in three planting sites. Plants were planted as bare-root or container-grown planting stock in the fall of 1975 and spring of 1976. Survival recorded in September 1978 and 1979.

Plant Species	Field Sites: G-3 1978	G-3 1979	G-17 1978	G-17 1979	Sect. 6 1978	Sect. 6 1979	Ave. Survival 1978	Ave. Survival 1979
	%	%	%	%	%	%	%	%
Greasewood	92	92	65	63	48	46	68	67
Fourwing saltbush	67	67	65	65	63	61	65	64
Shadscale	8	8	60	52	81	81	50	47
Cuneate saltbush	0	0	71	61	69	52	47	38
Winterfat	69	60	63	63	48	37	60	53
Greenes Rabbitbrush	71	61	77	77	0	0	49	46
Black sagebrush	83	77	90	88	2	0	58	55
Big sagebrush	88	77	85	85	27	17	67	60
Spreading rabbitbrush	38	19	50	33	0	0	29	17
Season + Method of Planting								
Fall								
Bare-root	46	44	45	44	30	28	40	39
Container	59	50	76	71	35	29	57	50
Spring								
Bare-root	56	49	74	68	39	35	56	51
Container	66	62	82	78	46	40	65	60
Season of Planting								
Fall	53	47	61	57	33	28	48	44
Spring	62	56	78	73	43	37	61	55
Propagation Method								
Bare-root	52	46	60	56	34	31	49	44
Container	63	56	79	75	41	34	61	55
Site	57	51	69	65	38	33	55	50

Table 11. Plant growth comparisons from nine shrubs using two methods of transplanting - bare-root and container-grown stock - at three locations and at two seasons of planting - Fall 1975 and Spring 1976. Data is shown for spring and fall observations during a two year period. Data are averages of three treatments and four replications at each location and expressed in square decimeters.

Species and Treatment		Drill Hole G-3				Drill Hole G-17				Section 6			
		1978		1979		1978		1979		1978		1979	
		June	Sept	June	Sept	June	Sept	June	Sept	June	Sept	June	Sept
		dm^2	dm^2	dm^2	dm^2	dm^2	dm^2	dm^2	dm^2	dm^2	dm^2	dm^2	dm^2
Greasewood	FBR	4.42	5.57	17.03	14.70	2.87	2.58	2.25	4.80	1.31	1.62	2.92	11.15
	SBR	3.27	3.36	12.67	11.20	0.98	1.79	1.72	2.50	1.25	2.50	3.58	12.00
	FCO	3.33	3.63	12.46	12.90	2.53	2.20	1.74	2.60	1.90	1.78	2.25	6.17
	SCO	3.07	3.46	10.92	9.60	2.28	2.44	2.42	4.20	1.12	9.00	1.47	5.07
Fourwing saltbush	FBR	15.30	17.00	6.50	9.50	1.90	3.44	2.25	5.00	0	0	0	0
	SBR	22.07	23.76	35.33	37.57	9.24	13.81	7.80	21.30	13.94	13.78	8.51	30.40
	FCO	18.00	20.80	33.60	40.27	7.29	9.67	4.14	19.00	6.12	7.03	3.92	27.50
	SCO	16.48	18.63	22.79	26.53	13.28	19.75	7.33	20.2	6.12	7.73	1.44	13.40
Shadscale saltbush	FBR	0	0	0	0	5.26	3.39	4.28	6.30	3.15	3.05	3.50	6.10
	SBR	11.00	12.50	7.50	3.50	6.98	7.01	6.17	10.70	5.07	5.35	4.98	8.60
	FCO	0	0	0	0	9.00	9.56	8.33	13.00	4.14	5.18	4.50	7.90
	SCO	11.30	10.63	21.63	19.10	12.97	13.04	12.06	21.20	2.46	2.62	2.85	5.80
Cuneate saltbush	FBR	0	0	0	0	10.64	11.25	8.25	24.90	1.32	1.40	1.08	4.10
	SBR	0	0	0	0	5.18	4.41	5.75	8.90	1.67	1.84	1.67	4.50
	FCO	0	0	0	0	11.35	7.74	9.17	15.40	2.47	2.56	3.38	13.50
	SCO	0	0	0	0	8.04	9.23	8.94	16.30	1.75	1.74	1.41	5.20
Winterfat	FBR	3.29	3.13	6.42	4.30	1.46	1.75	1.33	1.80	0.87	0.80	0.96	2.00
	SBR	3.92	3.14	8.72	4.00	1.91	2.13	1.39	1.70	0.50	0.42	0.92	1.75
	FCO	4.02	3.36	8.72	5.30	4.25	3.21	1.42	2.20	1.00	0.75	1.50	1.50
	SCO	3.26	3.11	6.79	3.80	4.18	4.17	2.69	3.60	0.89	0.77	1.81	4.57
Greenes rabbitbrush	FBR	4.71	5.09	15.67	11.06	2.25	2.44	1.60	1.90	0	0	0	0
	SBR	2.92	3.71	7.67	4.55	1.66	0.80	1.07	0.90	0	0	0	0
	FCO	2.56	2.93	7.25	3.92	2.93	3.04	1.83	2.40	0	0	0	0
	SCO	2.90	2.98	6.22	4.28	3.86	3.56	2.67	5.80	0	0	0	0
Black sagebrush	FBR	2.90	2.57	6.44	4.20	1.90	1.57	2.11	2.90	0	0	0	0
	SBR	2.51	2.25	5.45	3.00	2.42	2.23	2.29	3.40	0	0	0	0
	FCO	3.00	3.11	6.54	4.00	4.10	4.42	3.42	4.50	0.55	0.50	0	0
	SCO	1.61	1.52	3.09	2.00	1.28	1.19	1.60	2.10	0	0	0	0
Big sagebrush	FBR	4.64	5.04	12.38	6.80	2.61	2.81	3.37	5.20	1.06	0.88	1.32	2.12
	SBR	3.14	2.95	7.93	5.00	3.02	2.58	2.74	4.00	1.50	1.75	1.50	2.00
	FCO	6.27	5.79	12.00	9.50	6.50	6.19	5.21	9.20	1.77	1.99	2.33	3.83
	SCO	2.16	2.10	4.82	3.40	1.83	1.83	2.44	3.00	0	0	0	0
Spreading rabbitbrush	FBR	3.37	5.39	9.31	12.30	1.12	1.13	1.00	2.20	0.10	0	0	0
	SBR	1.00	0.10	0	0	1.00	1.34	0.85	1.70	0	0	0	0
	FCO	1.46	1.88	5.50	4.50	2.50	1.90	2.13	3.50	2.00	0	0	0
	SCO	2.31	2.91	8.50	8.00	1.89	1.77	1.17	1.80	0	0	0	0
Season of Planting & Propagation Method	FBR	5.52	6.26	10.54	8.98	3.33	3.37	2.94	6.11	1.30	1.55	1.96	5.09
	SBR	6.23	6.47	12.18	9.83	3.60	4.01	3.31	6.12	3.99	4.27	3.53	9.83
	FCO	5.52	5.93	12.30	11.48	5.61	5.33	4.15	7.98	2.49	2.83	2.98	10.07
	SCO	5.45	5.67	10.60	9.59	5.51	6.33	4.59	8.69	2.47	4.37	1.80	6.81
Season of Planting	FBR+CO	5.52	6.09	11.42	10.23	4.47	4.35	3.55	7.04	1.98	2.30	2.51	7.81
	SBR+CO	5.84	6.07	11.34	9.70	4.56	5.17	3.95	7.41	3.30	4.32	2.74	8.48
Propagation Method	BR	5.90	6.37	11.36	9.41	3.47	3.69	3.12	6.12	2.65	3.04	2.81	7.70
	CO	5.48	5.79	11.39	10.47	5.56	5.83	4.37	8.33	2.48	3.47	2.44	8.59

Date of seeding: Fall - November 13-14, 1975
Spring - March 23, 1976

Table 12. Plant growth of nine shrub species following three and four years in three planting sites. Plants were planted as bare-root or container-grown planting stock in the fall of 1975 and spring of 1976. Growth recorded in square decimeters in September 1978 and 1979 as plant cover.

Plant Species	Field Sites: G-3 1978	G-3 1979	G-17 1978	G-17 1979	Sect. 6 1978	Sect. 6 1979	Ave. Growth 1978	Ave. Growth 1979
	dm^2	dm^2	dm^2	dm^2	dm^2	dm^2	dm^2	dm^2
Greasewood	4.01	12.10	2.25	3.52	3.72	8.60	3.33	8.07
Fourwing saltbush	20.05	28.47	11.67	16.37	9.51	23.77	13.74	22.87
Shadscale	11.56	11.30	8.25	12.80	4.05	7.10	7.95	10.40
Cuneate saltbush	0.00	0.00	8.16	16.37	1.88	6.82	5.02	11.59
Winterfat	3.18	4.35	2.81	2.32	0.68	2.45	2.22	3.37
Greenes rabbitbrush	3.68	5.95	2.46	2.75	0.00	0.00	3.07	4.35
Black sagebrush	2.36	3.30	2.35	3.23	0.50	0.00	1.74	3.26
Big sagebrush	3.97	6.17	3.35	5.35	1.54	2.65	2.95	4.72
Spreading rabbitbrush	2.57	8.27	1.53	2.30	0.00	0.00	2.05	5.29
Season + Method of Planting								
Fall								
Bare-root	6.26	8.98	3.37	6.11	1.55	5.09	3.73	6.73
Container	5.93	11.48	5.33	7.98	2.83	10.07	4.70	9.84
Spring								
Bare-root	6.47	9.83	4.01	6.12	4.27	9.88	4.92	8.61
Container	5.67	9.59	6.33	8.69	4.37	6.81	5.46	8.36
Season of Planting								
Fall	6.09	10.23	4.35	7.04	2.30	7.81	4.25	8.36
Spring	6.07	9.70	5.17	7.41	4.32	8.48	5.19	8.53
Method of Planting								
Bare-root	6.37	9.41	3.69	6.12	3.04	7.70	4.37	7.74
Container	5.79	10.47	5.83	8.33	3.47	8.59	5.03	9.13
Site	6.08	9.97	4.76	7.23	3.25	7.96	4.70	8.39

Table 13. Comparison of direct seeding nine shrub species at three locations and at two planting dates - Fall 1975 and Spring 1976. Data shows total number of plants from 4 replications at nine observation dates.

Species and Time of Planting	Drill Hole G-3									Drill Hole G-17									Section 6								
	1976 Apr 27	1976 Jun	Oct	1977 Jun	Sep	1978 Jun	Sep	1979 Jun	Sep	1976 Apr 28	1976 Jun	Oct	1977 Jun	Sep	1978 Jun	Sep	1979 Jun	Sep	1976 Apr 27	1976 Jun	Oct	1977 Jun	Sep	1978 Jun	Sep	1979 Jun	Sep
	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No
Greasewood																											
Fall	7	25	8	8	4	5	5	4	4	0	0	0	0	0	0	0	0	0	10	1	0	0	0	0	0	0	0
Spring	0	17	8	7	6	6	6	5	5	18	10	0	0	0	0	0	0	0	4	12	4	2	2	3	3	3	3
Fourwing saltbush																											
Fall	1	4	3	3	2	2	2	2	2	0	1	0	0	0	0	0	0	0	4	1	1	1	1	2	1	1	1
Spring	0	58	26	17	8	8	8	6	6	18	8	0	4	2	2	1	1	2	10	63	38	39	32	28	28	19	19
Shadscale																											
Fall	0	0	0	0	0	0	0	14	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Spring	0	0	2	0	0	0	0	39	5	0	0	0	0	0	0	0	0	0	0	4	2	0	0	0	0	0	0
Cuneate saltbush																											
Fall	0	1	0	0	0	0	0	16	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Spring	0	2	0	1	1	0	0	28	2	0	0	0	0	0	0	0	0	0	0	1	0	2	0	0	0	0	0
Winterfat																											
Fall	6	27	15	11	11	10	11	5	7	1	0	0	0	0	0	0	0	0	16	39	14	11	9	8	6	4	4
Spring	0	22	16	9	10	6	6	3	3	7	12	0	0	0	0	0	0	0	3	9	9	8	6	7	7	7	7
Greenes rabbitbrush																											
Fall	2	4	4	3	2	3	2	1	1	0	0	0	0	0	0	0	0	0	3	3	1	0	0	0	0	0	0
Spring	0	2	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0
Black sagebrush																											
Fall	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	4	2	1	1	1	0	0	0
Spring	0	0	0	0	0	0	0	0	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Big sagebrush																											
Fall	1	7	6	6	5	5	6	6	6	0	0	0	0	0	0	0	0	0	2	2	3	2	2	2	2	2	2
Spring	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Spreading rabbitbrush																											
Fall	3	9	5	6	3	3	3	3	3	3	4	0	0	0	0	0	0	0	18	16	2	0	0	0	0	0	0
Spring	0	8	3	3	3	3	3	2	2	0	2	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0

Date of seeding: Fall - November 13-14, 1975
Spring - March 23, 1976

Table 14. Field survival of five grass species after 3 or 4 years[1] in three planting sites. Plants were planted as bare-root or container-grown stock in fall 1975 and spring 1976.

Species	Treat-ment	Drill Hole G-3 June 1976	June 1977	June 1978	Drill Hole G-17 June 1976	June 1977	June 1978	June 1979[1]	Section 6 June 1976	June 1977	June 1978
		%	%	%	%	%	%	%	%	%	
Indian ricegrass	FBR	33	17	0	58	25	25	17	0	0	0
	SBR	83	83	75	92	83	75	33	83	22	0
	FCO	75	75	75	75	75	75	50	50	25	17
	SCO	83	83	83	42	17	8	8	100	42	33
Needle & thread grass	FBR	58	25	8	83	42	42	33	8	0	0
	SBR	67	67	67	83	58	58	33	50	8	8
	FCO	67	58	58	83	42	42	25	100	8	0
	SCO	100	100	83	92	92	92	58	92	0	0
Fairway crested wheatgrass	FBR	83	42	42	75	17	17	17	58	8	0
	SBR	100	92	83	100	92	67	33	100	50	8
	FCO	67	67	67	100	83	75	75	100	42	17
	SCO	83	83	83	92	75	75	67	83	25	0
Western wheatgrass	FBR	100	83	58	83	67	67	58	92	75	33
	SBR	83	83	67	92	67	67	42	100	100	53
	FCO	100	100	100	100	92	92	92	100	92	83
	SCO	92	75	75	100	92	92	83	92	75	58
Bluebunch wheatgrass	FBR	75	58	42	67	25	25	8	92	17	0
	SBR	75	58	50	75	58	42	25	100	33	0
	FCO	83	83	50	83	83	83	67	92	33	0
	SCO	100	92	83	83	67	67	67	92	17	0
Season of Planting & Propagation Method											
	FBR	69.8	45.0	30.0	73.2	35.2	35.2	26.6	50.0	20.0	6.6
	SBR	81.6	76.6	68.4	88.4	71.6	61.8	33.2	86.6	42.6	14.8
	FCO	78.4	76.6	70.0	88.2	75.0	73.4	61.8	88.4	40.0	23.4
	SCO	91.6	86.6	81.4	81.8	68.6	66.8	56.6	91.8	31.8	18.2
Season of Planting											
	FBR+CO	74.1	60.8	50.0	80.7	55.1	54.3	44.2	69.2	30.0	15.0
	SBR+CO	86.6	81.6	74.9	85.1	70.1	64.3	44.9	89.2	37.2	16.5
Propagation Method											
	BR	75.7	60.8	49.2	80.8	53.4	48.5	29.9	68.3	31.3	10.7
	CO	85.0	81.6	75.7	85.0	71.8	70.1	59.2	90.1	35.9	20.8

[1] Due to contamination from natural seedlings, observation data for June 1979 was obtained only from the G-17 location.

Table 15. Grass seedling survival from direct seeding over a three-year (four years at Site G-17) for five grass species at three sites. Seedling survival is shown as the total number of seedlings from four replications comparing fall and spring planting dates.

Species	Time of Planting	Drill Site G-3				Drill Site G-17					Section 6			
		Apr 27[1] 1976	June[1] 1976	June 1977	June 1978	Apr 28[1] 1976	June[1] 1976	June 1977	June 1978	June[2] 1979	Apr 22[1] 1976	June[1] 1976	June 1977	June 1978
		No	No	No	No	No	No	No	No	No	No	No	No	No
Indian ricegrass	Fall	2	4	0	30	4	5	2	167	63	5	4	8	50
	Spring	1	1	3	362	1	3	0	187	105	0	0	0	201
Needle & thread	Fall	2	3	7	6	7	8	11	22	3	5	10	6	3
	Spring	0	3	2	5	0	2	0	20	0	0	4	0	15
Fairway crested wheatgrass	Fall	4	5	10	4	15	13	19	11	2	22	16	17	18
	Spring	1	12	13	12	8	13	0	3	0	0	14	0	0
Russian wild rye-grass	Fall	5	3	0	0	6	6	1	4	0	14	7	3	2
	Spring	0	10	9	9	1	13	0	0	2	0	13	0	0
Bottlebrush	Fall	4	6	1	0	16	12	7	11	1	22	15	7	2
	Spring	0	11	0	2	5	11	0	2	1	0	16	1	0

[1]The seedlings for April 27, 1976 and June 1976 were greater in number than indicated. The number of plants shown for June 1977, 1978 and 1979 (Site G-17 only) are the acutal number of live plants.

[2]Due to contamination from other grass plants, a grass seedling count for June 1979 was made only at Site G-17.

Date of fall planting - Nov. 14, 1975
Date of spring planting - March 23, 1976

of planting as well as summary information are shown on Table 8. Summary survival data for fall observations for 1978 and 1979 are shown in Table 9. Average survival comparing the two methods of planting at three sites are shown in Figure 3. It will be observed from the graphs that there was indication of the shrubs starting to level off in plant losses during the third growing season. By the fourth season they appear to be at equilibrium with the environment and considered to be established and able to compete with other competition for moisture and nutrients. Similar curves with survival plants being well established during the fourth growing season are shown in Figure 4 when comparing seasons of planting. This data graphically shows that plants need to be observed for at least three to four years when studying survival under these arid conditions. Differences in survival at the three locations are assumed to be due to plant adaptation under different soils, water holding capacity of the various soils, annual plant competition and rodents. The study sites at drill site G-3 and Section 6 had high annual plant competition with the plants in Section 6 being exposed to rodent damage. The plants located at Drill Site G-17 had less annual plant competition and little rodent grazing.

Plant growth expressed as plant cover for the nine shrubs discussed above are found in Tables 11 and 12. There was no particular difference in growth due to season of planting or between bare-root and container methods of planting as shown in Figures 5 and 6.

Direct seeding of shrubs is not dependable as the major method for rehabilitating an arid site as shown in the results on Table 13. Some of the original seeds that germinated in the spring of 1976 died rapidly and never were counted. Others such as cuneate and shadscale

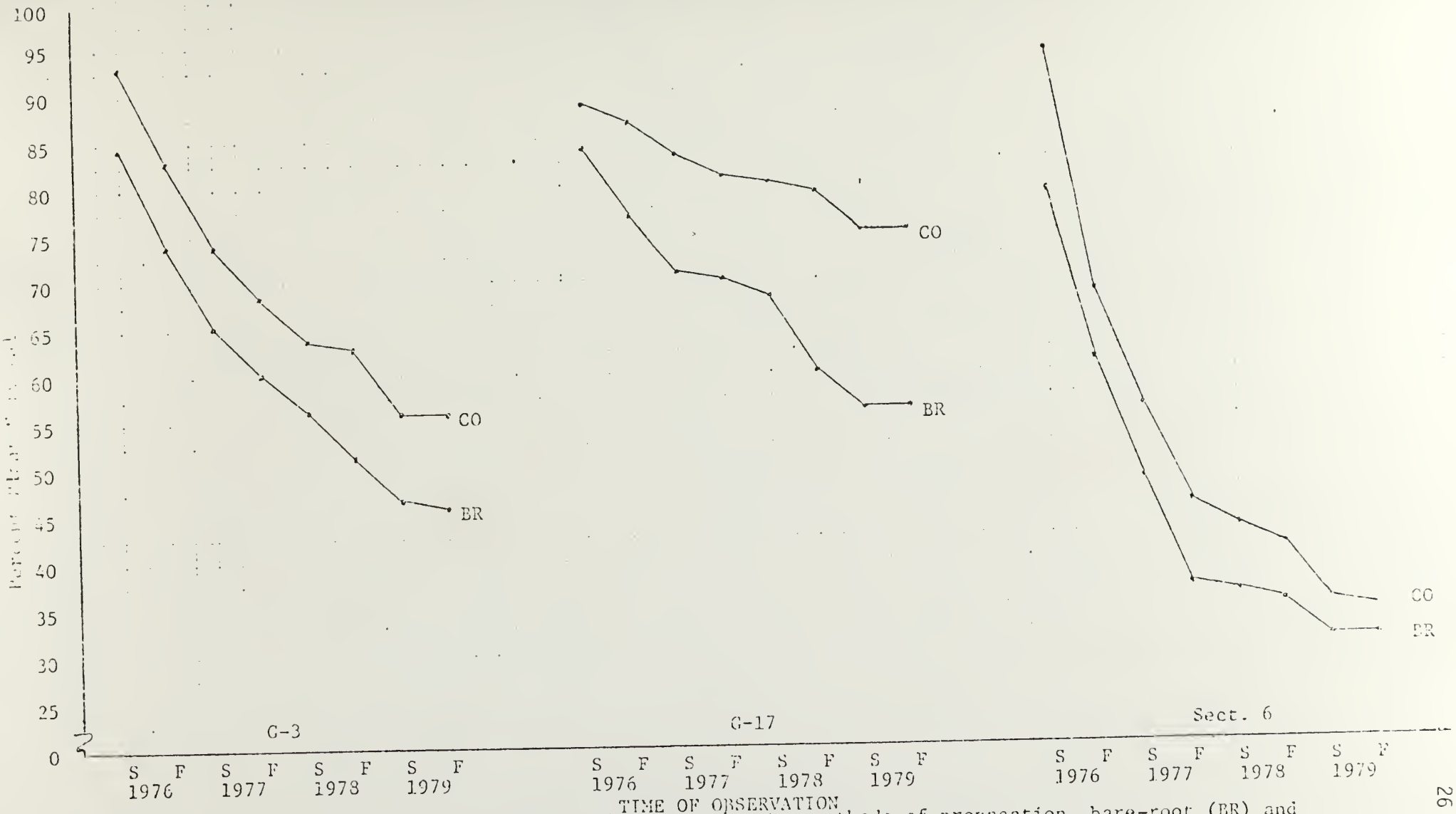


Fig. 3. Average survival of nine shrub species comparing two methods of propagation, bare-root (BR) and container (CO) grown stock at three locations. The two seasons of planting, spring and fall are averaged within the data.

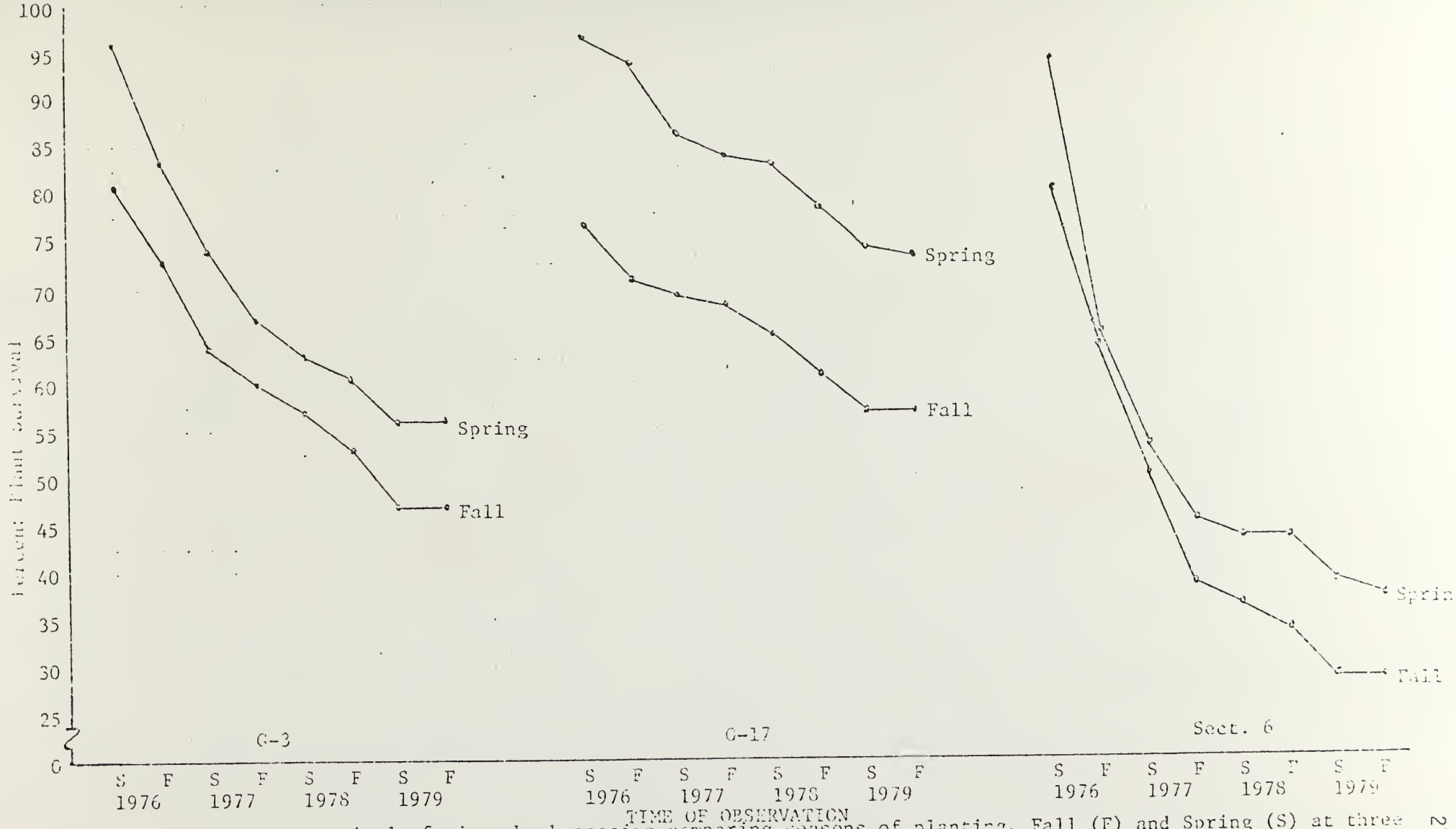


Fig. 4. Average survival of nine shrub species comparing seasons of planting, Fall (F) and Spring (S) at three locations. Two methods of propagation, bare-root and container are averaged within the data.

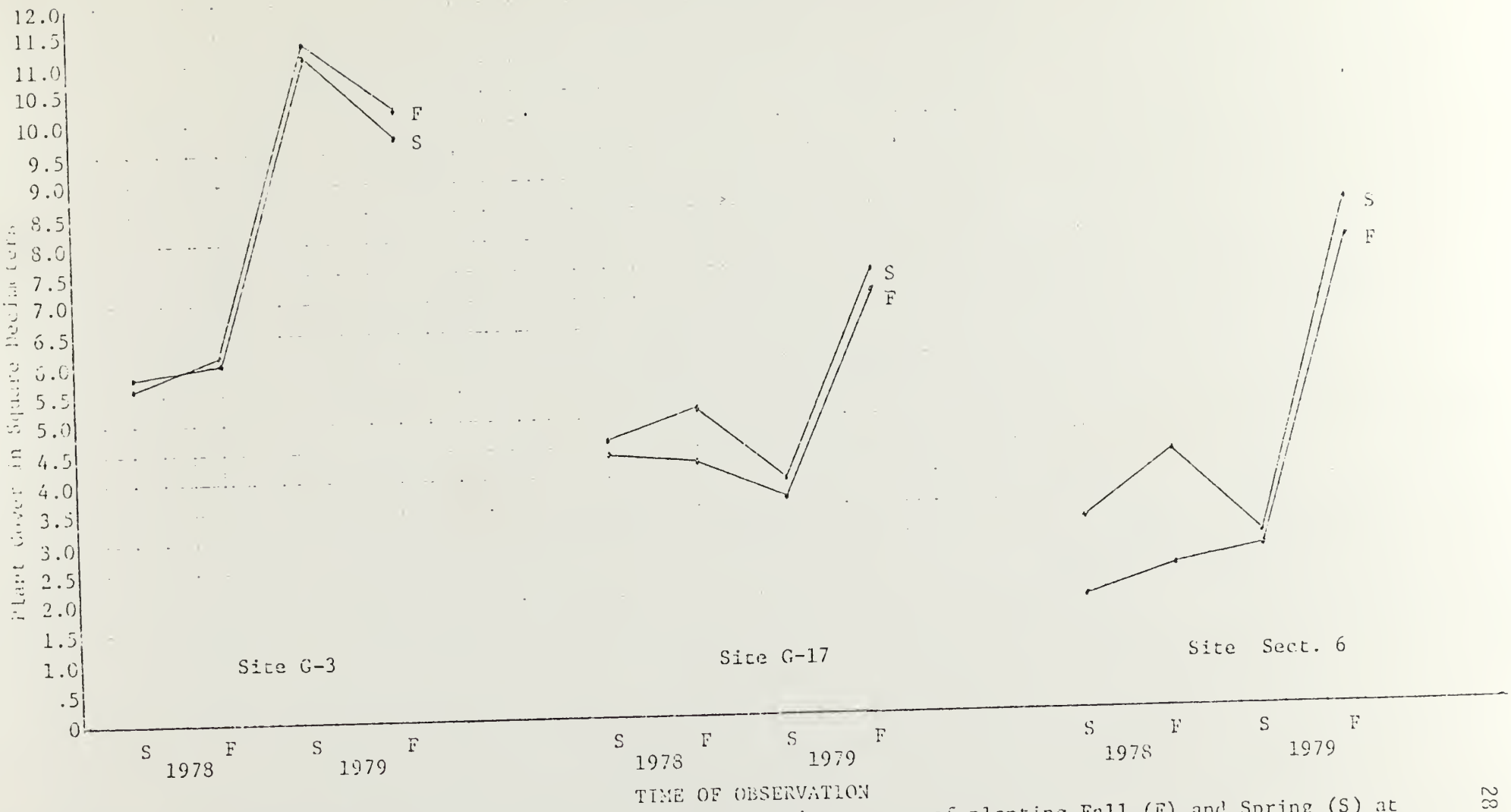


Fig. 5. Average plant growth of nine shrub species comparing season of planting Fall (F) and Spring (S) at three locations. Two methods of propagation - bare-root and container are averaged within the data.

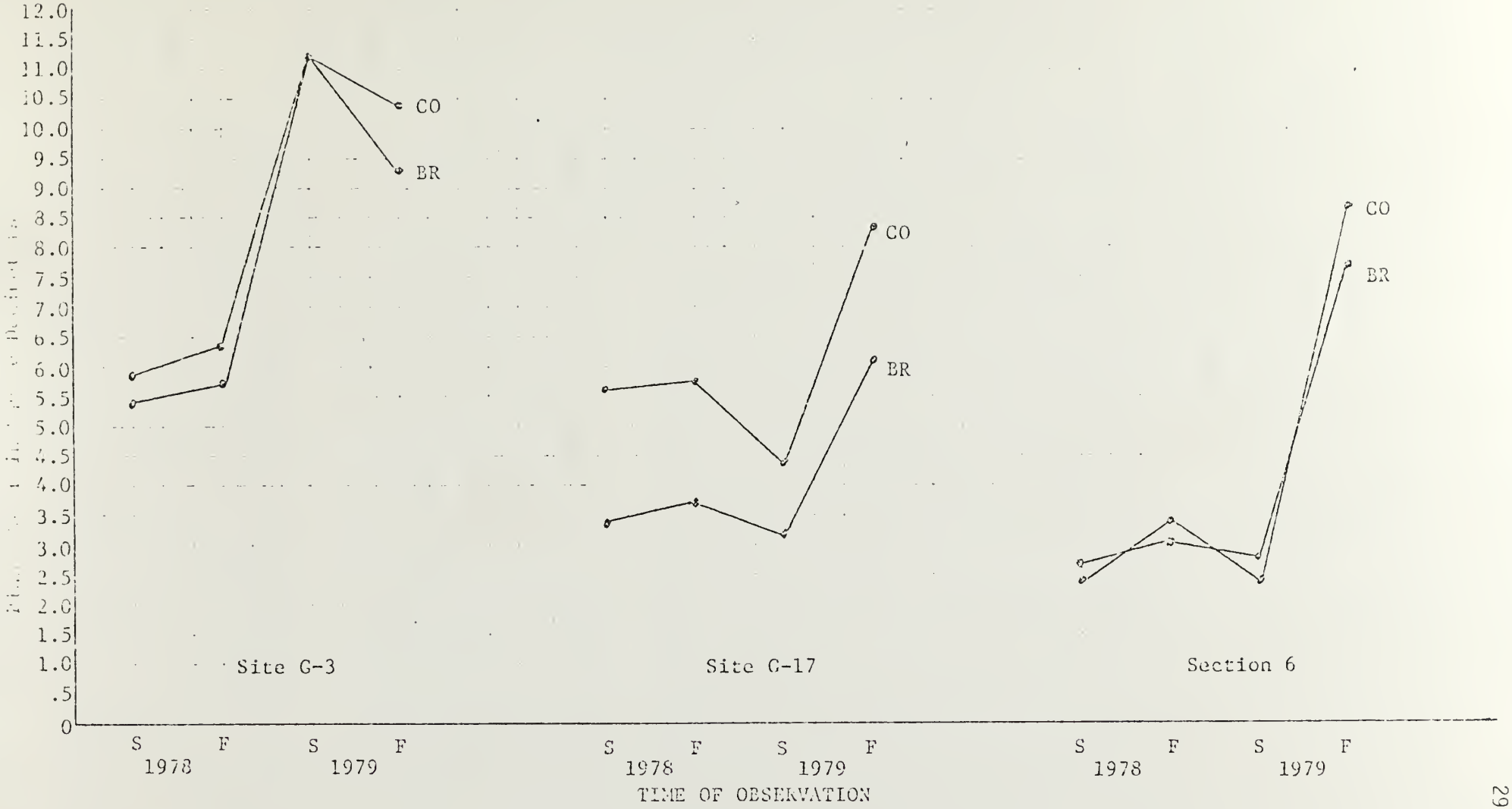


Fig. 6. Average plant growth of nine shrub species comparing two planting methods, bare-root (BR) and container (CO) grown stock during the third and fourth growing seasons following planting. The two seasons of planting, fall and spring are averaged in the data.

saltbushes showed rather good germination at Site G-3 during the spring of the fourth year following planting and then rather completely died out. Seedlings of these two species did not occur at the other two sites. Most seedlings still alive in the fall of 1979 are growing well and are probably well established.

Survival of five grass species planted at the three locations and comparing two seasons of planting and two methods of planting are shown in Table 14. Survival data was obtained only in the spring of each year, due to grasses going dormant making fall survival reading too unpredictable. No data was obtained from Sites G-3 and Section 6 in 1979 due to other grassy plant competition at Site G-3 and lack of plants at Section 6. Competition from annual plants greatly affected the survival of grasses at these locations and they were disastrous at Section 6 along with rodent grazing. Planting of grasses as bare-root or container-grown clones would be a highly suitable method if competition from other plants could be controlled until the shallow rooted grasses are well established.

Seedling count of five grasses over a three to four year period that were planted by direct seeding are shown in Table 15. Differences were observed between germination from fall or sping plantings. Most noticeable was the delay in germination of Indian ricegrass seed until the spring of 1978. This is natural with this species due to seed dormancy.

D. Plantings in processed shale and soil over shale-filled pits

These plantings are discussed on pages 53-59 of the Final Report (1978) with general conclusions. Continual survival data for the four growing seasons since field planting in April, 1976 are shown in Tables 16 and 17. The salt tolerant chenopods show the best survival

Table 16. Comparison of Utah and Colorado Parahp Processed Shale on survival of eight native container-grown shrub species over a four year period in the field. Shown are two dates of observation for each year.

Species	Time of Observation	Shale[1] Utah	Shale[1] Colo	Soil Over Shale[1] Utah	Soil Over Shale[1] Colo
		%	%	%	%
Fourwing saltbush	1976 - Spring	100	83	100	100
	Fall	17	67	100	100
	1977 - Spring	100[2]	83	100	100
	Fall	33	83	100	100
	1978 - Spring	33	83	100	100
	Fall	17	83	100	83
	1979 - Spring	17	83	83	67
	Fall	17	83	67	33
Cuneate saltbush	1976 - Spring	100	83	100	100
	Fall	0	33	83	83
	1977 - Spring	100[2]	83	67	83
	Fall	0	83	67	83
	1978 - Spring	0	83	67	83
	Fall	0	83	50	83
	1979 - Spring	0	83	50	67
	Fall	0	83	50	67
Shadscale saltbush	1976 - Spring	83	100	100	100
	Fall	0	100	100	100
	1977 - Spring	100[2]	100	100	100
	Fall	17	100	100	100
	1978 - Spring	0	100	83	100
	Fall	0	100	67	100
	1979 - Spring	0	100	67	83
	Fall	0	100	67	83
Greasewood	1976 - Spring	67	83	100	100
	Fall	0	50	50	100
	1977 - Spring	100[2]	50	100[2]	100
	Fall	17	50	50	100
	1978 - Spring	0	50	50	100
	Fall	0	50	50	83
	1979 - Spring	0	50	50	83
	Fall	0	50	50	83
Black sagebrush	1976 - Spring	100	67	100	83
	Fall	0	0	0	0
	1977 - Spring	100[2]	0	100[2]	0
	Fall	0	0	0	0
	1978 - Spring	0	0	0	0
	Fall	0	0	0	0
	1979 - Spring	0	0	0	0
	Fall	0	0	0	0
Douglas rabbitbrush	1976 - Spring	33	67	83	100
	Fall	0	0	0	0
	1977 - Spring	0	0	0	0
	Fall	0	0	0	0
	1978 - Spring	0	0	0	0
	Fall	0	0	0	0
	1979 - Spring	0	0	0	0
	Fall	0	0	0	0
Winterfat	1976 - Spring	67	100	100	100
	Fall	17	67	67	100
	1977 - Spring	100[2]	33	100[2]	67
	Fall	0	33	17	67
	1978 - Spring	0	33	17	50
	Fall	0	33	0	33
	1979 - Spring	0	33	0	33
	Fall	0	33	0	33
Big sagebrush	1976 - Spring	100	50	100	67
	Fall	0	0	67	50
	1977 - Spring	0	0	50	33
	Fall	0	0	0	33
	1978 - Spring	0	0	0	33
	Fall	0	0	0	33
	1979 - Spring	0	0	0	17
	Fall	0	0	0	17

[1] Shale consists of 90 cm of parahp processed shale from each site. Soil over shale consists of 15 cm of parahp processed shale from each site overlaid with 15 cm of local soil.

Table 17. Effect of Paraho Processed Shale on performance of container-grown grass and forb species. Summary of four replications[1] showing percent survival at two yearly observation dates over a four-year period.

Species	Treatment[2]	1976		1977		1978		1979	
		June	Sept	June	Sept	June	Sept	June	Sept
		%	%	%	%	%	%	%	%
Indian ricegrass	Shale	94	0	0	0	0	0	0	0
	Soil over shale	100	19	0	0	6	0	0	0
Sand dropseed (Reps 1 and 2)	Shale	87	13	0	0	0	0	0	0
	Soil over shale	100	13	0	0	0	0	0	0
Russian wild ryegrass (Reps 3 and 4)	Shale	100	0	0	0	0	0	0	0
	Soil over shale	100	37	37	13	0	0	0	0
Western wheatgrass	Shale	81	0	0	0	0	0	0	0
	Soil over shale	100	100	100	50	50	0	0	0
Needle & thread grass	Shale	94	0	0	0	0	0	0	0
	Soil over shale	94	6	0	0	0	0	0	0
Saltgrass	Shale	100	19	6	6	13	0	0	0
	Soil over shale	100	44	19	19	19	0	0	0
Seepweed	Shale	81	63	56	50	37	44	44	44
	Soil over shale	100	100	94	87	87	87	69	69
Kochia prostrata	Shale	87	44	19	19	25	19	19	13
	Soil over shale	100	87	75	75	69	63	31	31

[1]There were four plants per replication in each growth material or a total of sixteen. Sand dropseed was planted in replications one and two only, and Russian wild ryegrass in replications three and four. Lack of available plants was the reason.

[2]Shale treatment consists of 30 cm of Paraho processed shale. Soil over shale consists of 15 cm of Paraho processed shale overlaid with 15 cm of local soil.

Planting date - April 9 thru April 27, 1976.

in the shrub study and seepweed (Suaeda fruticosa) and Kochia prostrata are the only two species living in the grass-forb study.

There were numerous halogeton seedlings in June, 1979 scattered where soil overlaid the shale and quite a few growing in the straight shale. Those in the shale were in most cases growing where the soil core remained from where a plant had died. This was more noticeable in the shrub study. A few cheatgrass plants were found growing in the soil over shale treatments. Natural weathering of the shale seems to be conducive in initiating physical and chemical changes allowing seed germination and growth of some annual plants, thereby starting environmental changes.

E. Plantings in water harvesting basins

These 40 basins at Section 6 were initially constructed in July, 1976 and following previous treatments and data, a container-grown fourwing saltbush was planted in the bottom of each basin. The early treatments and results are discussed in the 1978 final report on pages 136-143. By the fall of 1978 all 20 plants in the small basins of the 20 planted were still alive. Plant survival was reduced to 16 by the fall of 1979. In the large basins, only 7 plants out of 20 survived the second growing season and these were reduced to 5 by the fall of 1979. Poor large basin design resulted in the harvested water percolating into the soil too far out from the transplant. This allowed for an abundant growth of annuals, particularly halogeton, which utilized the moisture rather than making it available for the fourwing saltbush. The abundant growth of the annual competition also made an ideal habitat for rodents, which in turn severely grazed the saltbushes. This condition did not occur in the small basins, as the annuals that did grow remained relatively small.

F. Pilot model

This "Pilot Model"using processed shale is discussed in the Final Report of 1978 from pages 143-160. Scattered halogeton seedlings were growing in the processed shale on the slopes. A number of these died in early summer. A few remained alive most of the summer but with very little growth. It is expected that more seedlings will germinate and grow on these shale slopes as the shale weathers and organic matter, though limited, accumulates. Halogeton, along with some cheatgrass and a few Russian thistle seedlings, grew quite abundantly on the soil filled trench utilizing available moisture intended for the plants being established. The survival and growth of the five species planted April 4, 1977 on the soil filled trench are shown in Table 18. This data covers the 3 growing seasons since they were field planted. Some of these plants, especially fourwing saltbush have been quite heavily grazed.

G. Field establishment and planting methods

The four initial plantings made at Sites G-5, G-8, G-13 and G-22 in April, 1975 are discussed in the 1978 Final Report on pages 173-182. Site G-8 was replanted April 1, 1977 to a plant competition study, due to a poor establishment of the original bare-root transplants. The major reason for the first failure at Site G-8 was due to the soil being dry at time of planting.

The plants at the remaining three sites have gone through five growing seasons with the numbers of plants remaining rather constant since the fall of 1978. This would infer that the plants are well established and have stabilized with environmental conditions. Plant survival at these locations are shown in Table 19.

Table 18. Survival and Growth of Plants in the Topsoil Trench of the Oil Shale Disposal Pilot Model. Data are from single plants over three-year period. Date of planting-April 4, 1977.

Species	Paraho Process				Union Process			
	A 1/		B		C		D	
	Rating 2/	Height cm	Rating	Height cm	Rating	Height cm	Rating	Height cm
Kochia prostrata								
June 9, 1977	2	20	2	30	2	28	2	30
June 13, 1978	2	29	2	37	2	42	2	36
Sept. 7, 1978	1	22	2	39	2	55	2	56
June 13, 1979	2	55	2	47	2	46	2	42
Sept 20, 1979	2	55	2	57	2	73	2	72
Shadscale								
June 9, 1977	2	5	2	5	2	6	2	2
June 13, 1978	0	0	0	0	2	18	2	5
Sept. 7, 1978	0	0	0	0	2	20	2	2
June 13, 1979	0	0	0	0	2	16	1	5
Sept. 20, 1979	0	0	0	0	2	17	1	5
Fourwing saltbush								
June 9, 1977	2	43	2	62	2	51	2	37
June 13, 1978	2	47	2	53	2	75	2	64
Sept. 7, 1978	1	41	1	45	2	83	2	67
June 13, 1979	2	52	2	45	2	62	2	55
Sept. 20, 1979	2	50	2	45	2	76	2	90
Cuneate saltbush								
June 9, 1977	2	8	2	7	2	6	2	5
June 13, 1978	2	34	2	21	2	32	2	17
Sept. 7, 1978	1	32	2	20	2	32	2	22
June 13, 1979	0	0	2	20	2	30	2	20
Sept. 20, 1979	0	0	2	22	2	23	2	22
Russian wildrye grass								
June 9, 1977	2	6	2	11	2	11	2	12
June 13, 1978	0	0	2	66	2	79	2	51
Sept. 7, 1978	0	0	1	217	2	77	2	22
June 13, 1979	0	0	1	35	2	30	2	27
Sept. 7, 1979	0	0	2	15	2	18	2	26

1/ A - Control
B - Surface stabilized
C - Control
D - Surface stabilized

2/ Rating 0 = dead
1 = poor to fair vigor
2 = good to excellent vigor

Table 19. Percent Plant Survival at Three Disturbed Locations on September 20, 1979

Method of Planting and Plant Name	Sites G-5 %	G-22 %	G-13 %
Bare-root Stock			
Greasewood	25	18	28
Fourwing saltbush	43	25	68
Big sagebrush	43	13	65
Winterfat	3	10	NP
Black sagebrush	38	15	NP
Shadscale	NP	NP	0
Cuneate saltbush	NP	NP	5
Rubber rabbitbrush	0	0	NP
Spreading rabbitbrush	NP	NP	58
Container Stock			
Fourwing saltbush	92	75	79
Cuneate saltbush	17	25	NP
Shadscale	0	0	NP
Saltgrass	30	NP	NP

NP = None planted

Plants at Sites G-5 and G-22 were subjected to heavy competition for moisture from annuals, especially Russian thistle, from the beginning as well as wildlife and sheep grazing. Fourwing saltbush when planted as large healthy container-grown transplants had excellent survival at these two locations.

Plant losses at Site G-13 are contributed almost entirely to wildlife grazing, especially rabbits.

H. Plantings on shale disposal pile, Anvil Point, Colorado

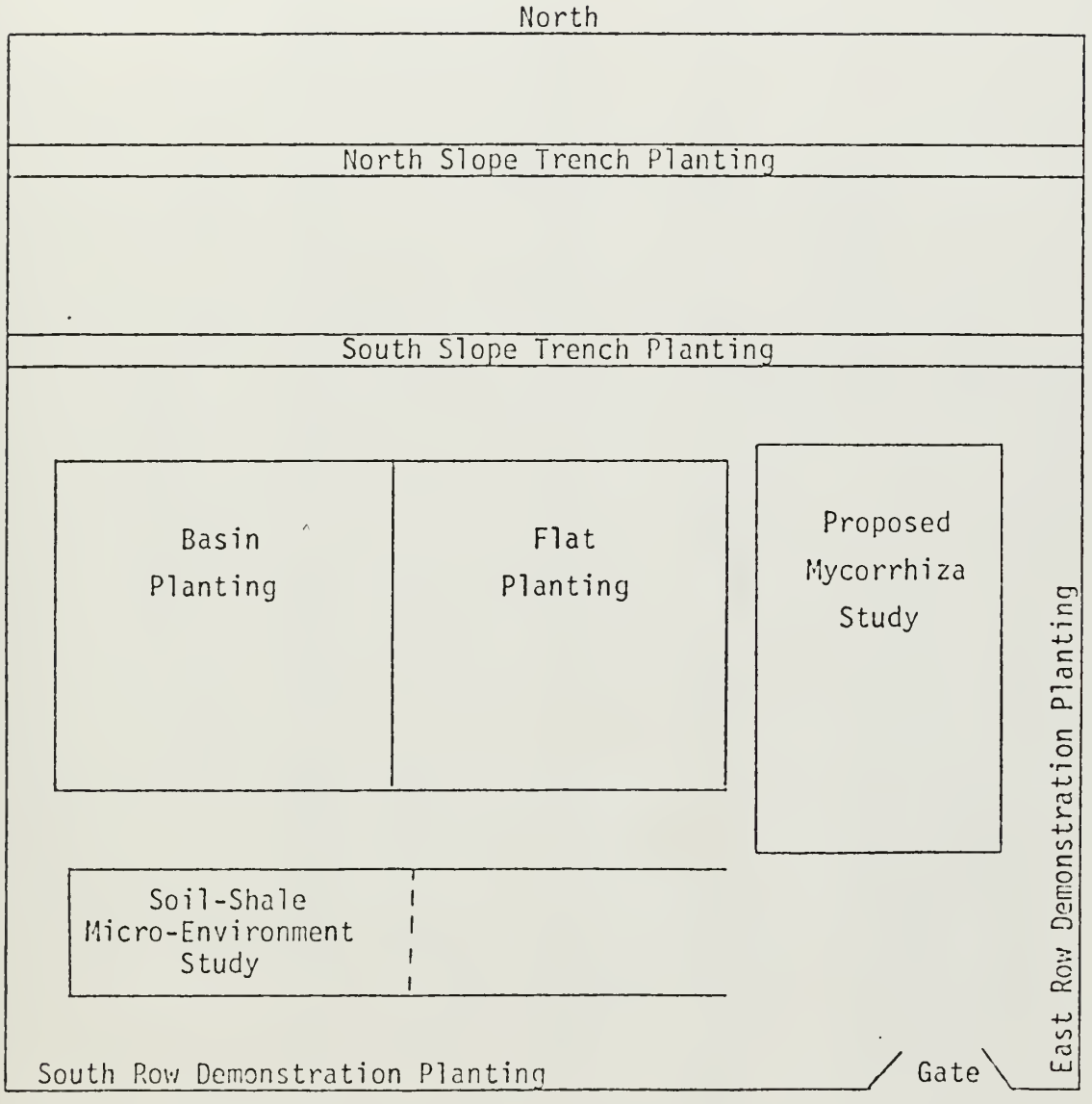
Preliminary studies at the Anvil Point site were mentioned in the 1978 Final Report pages 160-166.

On March 27, 1979 the north and south trenches on each side of the shale water harvesting slopes were filled with soil. Much of the soil was too wet and it resulted in large gumbo chunks. Some leveling and compaction of this soil in the trenches was accomplished though not too uniform. Demonstration plantings were made along the south fence from container-grown stock used in previous greenhouse studies on the above date.

Field plans and treatments for all plantings at this site are shown in Figures 7-11. The soil in the trenches was prepared in a seedbed condition on April 29, 1979 as well as digging the basins for planting. Soil was placed in alternate shallow furrows for the soil-shale Micro-Environment Study. The furrows were made by dragging the teeth of a heavy duty front-end tractor loader across the compacted processed shale.

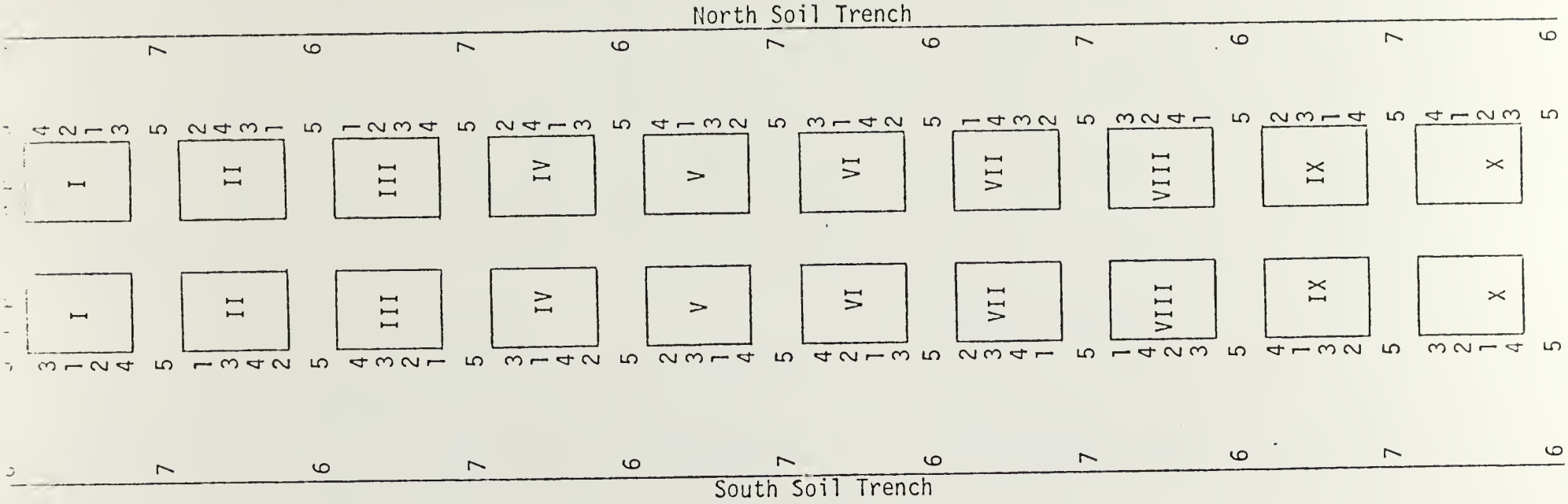
Plant survival and growth data are in Table 20-23. The survival and growth measurements on July 17 and September 19, 1979 for the first growing season have been rather astounding. Other than

Fig. 7. Plant Survival and Growth Studies
in Spent Shale
Anvil Point, Colorado
1979



General plot planting locations on the spent shale pile. Anvil Point, Colorado.

Fig. 8. Soil Trench Planting
Anvil Point, Colorado



To Plant Species:

1. Fourwing saltbush (*Atriplex canescens*)
2. Shadscale (*Atriplex confertifolia*)
3. Cuneate saltbush (*Atriplex cuneata*)
4. Western wheatgrass (*Agropyron smithii*)
5. Greasewood (*Sarcobatus vermiculatus*)
6. Siberian (Prostrate) cypress (*Kochia prostrata*)
7. Seepweed (*Suaeda spp.*)

Date of Planting:

April 26, 1979

Spacing:

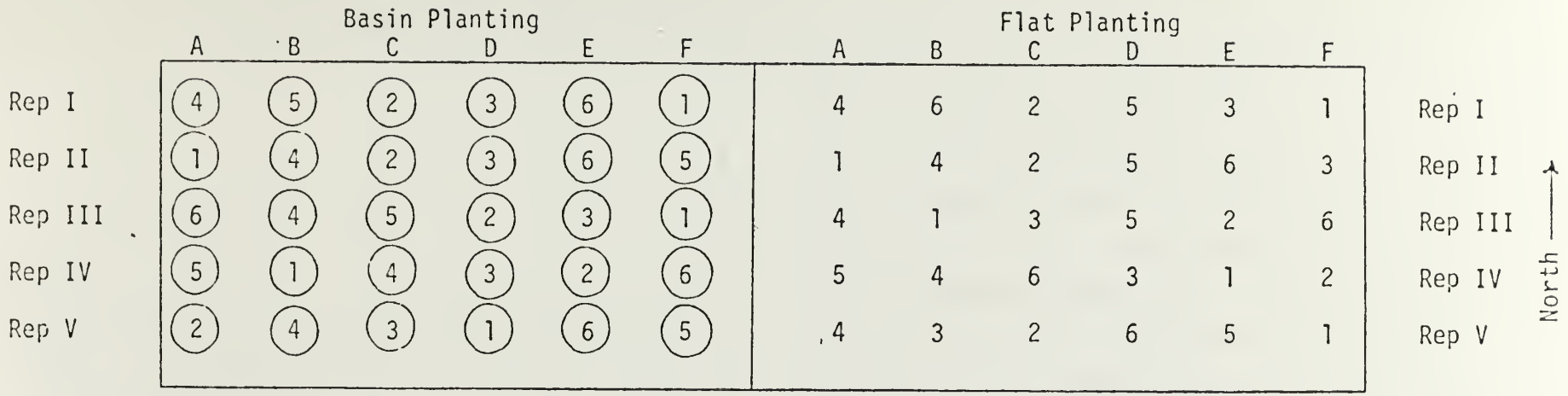
Approximately 70 cm. between plants in the row

NOTES:

1 l. of water applied per plant containing a soluble 20-20-20 fertilizer at .3 l. (1/4 cup) per 1.9 dkl (5 gal.) of water.

All plants container grown except for Kochia prostrata which was bare-root stock.

Fig. 9. Basin and Flat Planting Study
Anvil Point, Colorado



Shrub Species Planted:

1. Fourwing saltbush (*Atriplex canescens*)
2. Shadscale (*Atriplex confertifolia*)
3. Cuneate saltbush (*Atriplex cuneata*)
4. Western wheatgrass (*Agropyron smithii*)
5. Greasewood (*Sarcobatus vermiculatus*)
6. Seepweed (*Suaeda spp.*)

All plants container grown in following size containers:

Western wheatgrass and seepweed 2x2x6 inches
Greasewood 2.5x2.5x12 inches
All others 2x2x12 inches

Date of Planting:

April 26, 1979

Plant Spacing:
2 m between rows
2.5 m between replications

NOTE: All plants received 1 l. of water containing a soluble 20-20-20 fertilizer at .3 l. (1/4 cup) per 1.9 dkl (5 gal.) of water.

Fig. 10. Soil-Shale Micro-Environment Study
Anvil Point, Colorado

North ↑

	A	B	C	D	E	
Rep I	3	5	1	2	4	Soil in shallow furrow with plants
	-	-	-	-	-	Shallow furrow in spent shale
Rep II	5	1	4	3	2	Soil in shallow furrow with plants
	-	-	-	-	-	Shallow furrow in spent shale
Rep III	4	5	3	2	1	Soil in shallow furrow with plants
	-	-	-	-	-	Shallow furrow in spent shale
Rep IV	1	3	5	4	2	Soil in shallow furrow with plants
	-	-	-	-	-	Shallow furrow in spent shale
Rep V	2	3	4	1	5	Soil in shallow furrow with plants

Shrub Planting in Soil Furrow:

1. Fourwing saltbush (*Atriplex canescens*)
2. Shadscale (*Atriplex confertifolia*)
3. Cuneate saltbush (*Atriplex cuneata*)
4. Western wheatgrass (*Agropyron smithii*)
5. Mat saltbush (*Atriplex corrugata*)

Plants were all grown in 2x2x12 inch containers except Western wheatgrass which was grown in a 2x2x6 inch container. Container plantings extended in depth below the 4 to 5 inches of soil into the spent shale.

Spacing:

1 meter between plants in soil strips

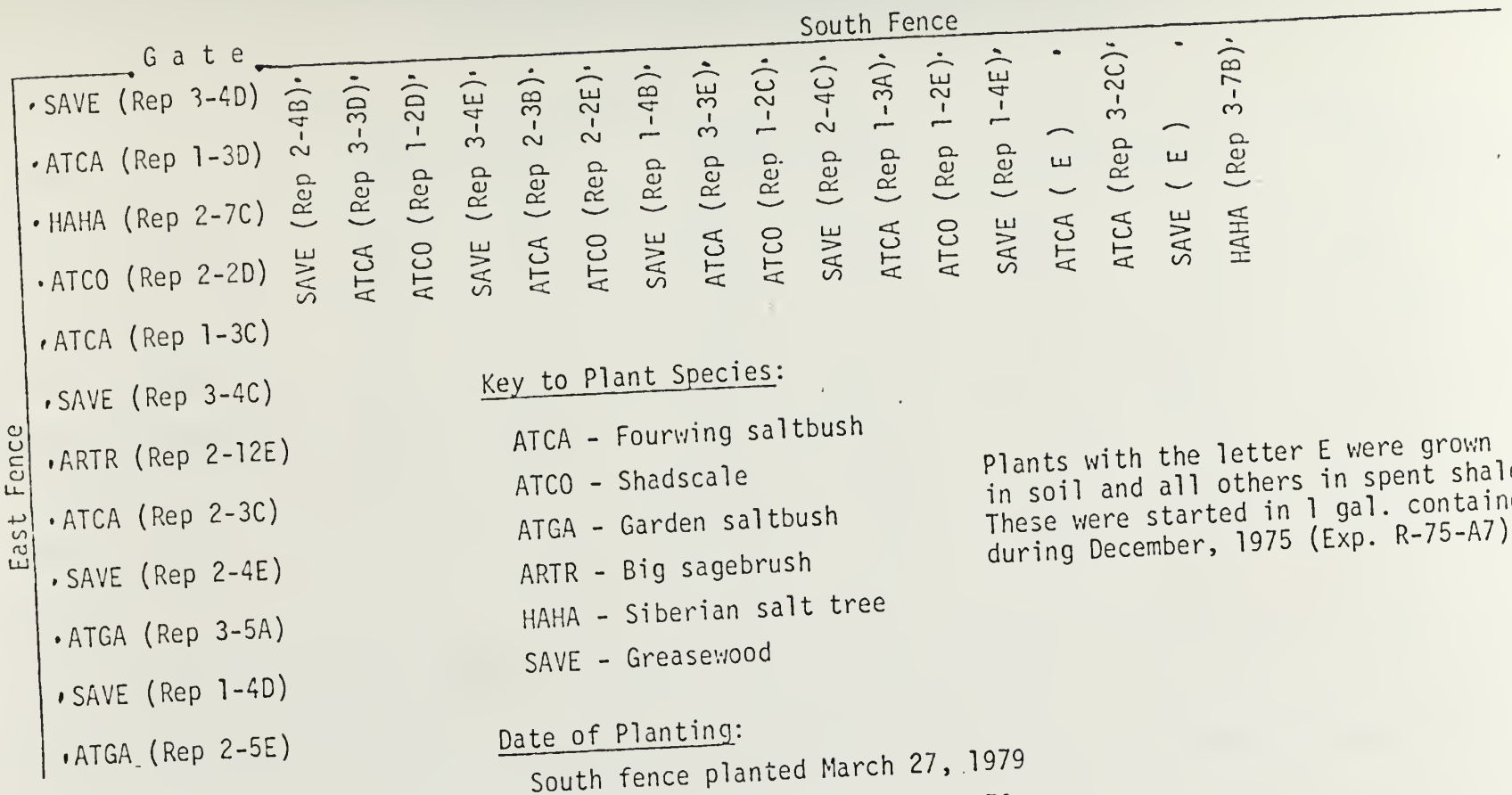
Approximately 50 cm between soil strips

Date of Planting:

April 27, 1979

NOTE: 1 l. of water applied per plant containing a soluble 20-20-20 fertilizer at .3 l. (1/4 cup) per 1.9 dkl (5 gal.) of water.

Fig. 11. Demonstration Planting
Anvil Point, Colorado



Key to Plant Species:

ATCA - Fourwing saltbush
ATCO - Shadscale
ATGA - Garden saltbush
ARTR - Big sagebrush
HAHA - Siberian salt tree
SAVE - Greasewood

Plants with the letter E were grown in soil and all others in spent shale. These were started in 1 gal. containers during December, 1975 (Exp. R-75-A7).

Date of Planting:

South fence planted March 27, 1979
East fence planted April 29, 1979

Spacing:

1 meter from fence and 1.5 m. between plants.

NOTE: All plants received 1 l. of water, April 29, 1979 containing a soluble 20-20-20 fertilizer at the rate of .3 l (.25 cup) per 1.9 dkl (5 gal.) of water. Each plant then received 3 l. of water.

Table 20. Plant Survival and Growth in the North and South Soil Trenches at Anvil Point, Colorado. Observations were Made on July 17 and September 19, 1979.

Species	Survival				Plant Height			
	North Trench		South Trench		North Trench		South Trench	
	July 17	Sept 19	July 17	Sept 19	July 17	Sept 19	July 17	Sept 19
	%	%	%	%	%	%	%	%
Fourwing saltbush	100	100	100	100	24.1	32.6	26.7	36.3
Shadscale	100	100	100	100	7.5	7.3	5.8	5.5
Cuneate saltbush	100	100	100	100	10.3	11.7	14.6	18.3
Western wheatgrass	100	100	100	100	23.7	21.0	21.7	15.8
Greasewood	100	100	100	100	21.0	29.8	24.5	31.6
Kochia prostrata	50	50	67	67	14.8	31.7	29.8	44.8
Seepweed	100	100	80	80	16.3	10.2	17.3	18.0

Date of planting - April 26, 1979

Data are the average of ten plants except for Kochia which is the average of 6 plants and seepweed of 5 plants.

Table 21. Comparison in Plant Survival and Growth of Six Species Planted in Basins for Water Harvesting or Level with Soil Material. Data obtained July 17 and September 19, 1979.

Species	Plant Survival				Plant Height			
	Basin Planting		Flat Planting		Basin Planting		Flat Planting	
	July 17	Sept 19	July 17	Sept 19	July 17	Sept 19	July 17	Sept 19
	%	%	%	%	cm	cm	cm	cm
Fourwing saltbush	100	100	100	100	27.2	38.6	27.8	34.6
Shadscale	100	100	100	100	5.2	4.8	7.6	6.6
Cuneate saltbush	100	100	100	100	9.0	12.2	12.8	13.2
Western wheatgrass	100	80	100	100	22.0	14.0	19.6	11.6
Greasewood	100	100	100	100	18.2	30.4	18.4	23.4
Seepweed	100	100	100	100	31.2	41.8	17.4	19.0

Date of planting - April 26, 1979 Anvil Point, Colorado

These were planted directly in the processed shale pile except for the small amount of soil material used in the various containers.

Table 22. Plant Survival and Growth Under a Soil-Shale Micro Environment with the Container-Grown Transplants Planted in Shallow Furrows Filled with Soil.

Species	Survival 1979		Plant Height 1979	
	July 17	Sept 19	July 17	Sept 19
	%	%	cm	cm
Fourwing saltbush	100	100	21.8	26.0
Shadscale	100	100	5.6	5.8
Cuneate saltbush	100	100	9.4	10.4
Western wheatgrass	100	100	18.2	13.2
Mat saltbush	100	100	6.4	9.4

Date of Planting: April 26, 1979 Anvil Point, Colorado

Table 23. Survival and Growth of a Miscellaneous Demonstration Planting Along the East and South Fences Within the Exclosure.

Species	East Fence					South Fence				
	Plants Planted	Survival July 17	Survival Sept 19	Height July 17	Height Sept 19	Plants Planted	Survival July 17	Survival Sept 19	Height July 17	Height Sept 19
	No.	%	%	cm	cm	No.	%	%	cm	cm
Fourwing saltbush	3	100	100	19.0	24.3	6	83	83	27.4	32.0
Shadscale	1	100	100	14.0	14.0	4	75	75	15.3	14.3
Gardner saltbush	2	100	100	7.0	7.5					
Big sagebrush	1	100	100	14.0	16.0					
Greasewood	4	100	100	19.5	26.0	6	100	100	18.8	23.5
Siberian salt tree	1	100	100	15.0	14.0	1	100	100	23.0	32.0

Date of Field Planting:

South fence - March 27, 1979
East fence - April 29, 1979

Readings were made:

July 17, 1979
September 19, 1979

Anvil Point, Colorado

The plants were grown in a greenhouse study initiated in December 1975 where the plants were grown either in processed shale or in regular soil.

Kochia prostrata on the edge of the trenches, there has been only one loss. The Kochia plants were small and in rather poor condition when planted and they were bare-root stock, while all others were container-grown stock. Precipitation was probably above normal during the growing season which accounted for the high rate of plant survival.

A few summer cypress (Kochia scoparia), halogeton and Russian thistle were growing in the soil in the trenches. Plants of halogeton and Russian thistle were also growing in the shale on the water harvest slopes as well as the flat area of shale between the two slopes.

Numerous Russian thistle and summer cypress plants were growing in the soil strips in the Micro-Environment.

It appears likely that most of these weed seeds were blown in, however, some could have been hauled in with the soil material. Most of the soil was obtained from below the surface.

I. Mycorrhizae studies - enhancement of plant survival

A study was established at the Section 6 field research site on June 24, 1978. Five plants each of Atriplex canescens were innoculated during greenhouse growth with an infusion of mycorrhizae obtained from 4 wing saltbush plants and soil in the test site. Five additional plants were not involved. After growth in the greenhouse until proper size for planting the plants were set out in a 20 ft. long trench 18 inches wide and 24" deep filled with Union-processed oil shale.

Mycorrhizal plants had a low % infection, $\approx$8.07% and these were mainly strings of hyphae and peletons, with very few vessicles and no arbuscules. Control plants had $<$1.0% infection by mycorrhizal fungi (Table 24).

Table 24. Effect of mycorrhizal innoculation on field performance of Atriplex canescens container-growth seedlings.

Treatment	Plant survival %	Mean increase in plant height (cm) 10/6/78	Mean increase in plant height (cm) 9/7/79	Mean cover % (m^2 quadrat) 9/7/79	Total mean biomass (g) 9/7/79
Mycorrhizal	100	2.80	22.0	30.0	28.02
control	80	2.40	20.00	8.6	11.02

In a companion study 5 mycorrhizal innoculated and 5 non innoculated cuttings were grown in the greenhouse until ready for outplanting. The ten plants were transplanted to a sterile subsoil band of an oil shale filled trench.

Mycorrhizal plants had 2.5% infection and these were only associated hyphae and a few peletons. Control plants had zero infection by mycorrhizal fungi (Table 25).

Table 25. Plant performance of mycorrhizal treated cuttings of Atriplex canescens in a narrow soil trench in Paraho Shale.

Treatment	Plant Survival %	Mean increase in plant height (cm) 10/6/78	Mean increase in plant height (cm) 9/7/79	Mean cover % (m^2 quadrat) 9/7/79	Total mean biomass (g) 9/7/79
Mycorrhizal	100	1.40	13.50	5.0	7.94
Control	80	0.60	6.90	1.6	2.96

Low infection rates on mycorrhizal plants in both shale and soil may be due in part to difficulties encountered in removal of tertiary

roots from the growing media at time of plant harvest. The encouraging results in plant height, cover and biomass indicate the value of mycorrhizal innoculation. Further studies are underway regarding enhancement of soil moisture uptake and phosphorus content by mycorrhizae treated plants. An additional study on mycorrhizae effects on plant survival is presently underway at Anvil points.

IV. HYDROLOGY STUDIES AT ANVIL POINTS

A study funded by the U S Department of Agriculture on funds made available from the Environmental Protection Agency was completed in 1979. A report from this study plus detailed leaching studies in the soil physics laboratory at USU in being prepared for submission to USDA. Copies of the report will be made available to the White River Shale project and Paraho for review.

V. BASELINE MONITORING STUDIES

A. Biomass production and plant cover

Productivity of understory vegetation (under the shrubs or tree cover) was sampled on June 12 and 13, 1979. As in the baseline study conducted in 1975-76, above-ground biomass was harvested from ten .25 meter plots in five different locations of each vegetation type the vegetation types sampled included shadscale, sagebrush-greasewood, Juniper and Riparian. Thus, the total number of plots harvested in each vegetation type was 50.

Notes on vegetation conditions were recorded relative to the density of plants and the patchiness of plant production in the more favorable sites for growth. Estimates of plant cover were also obtained where vegetation was measured.

1. Shadscale vegetation type.

Table 26. Biomass production of understory vegetation (gm/plot[1] in the shadscale vegetation type.

Replication	Location 1	2	3	4	5
1	.9	4.4	18.3	2.2	0
2	4.4	2.4	2.6	.9	2.6
3	2.0	3.8	3.6	0	1.4
4	1.4	10.8	8.2	4.2	1.1
5	2.1	5.0	2.9	.4	.5
6	1.8	3.5	2.8	5.6	4.4
7	5.1	.8	1.3	0	1.9
8	2.3	2.1	10.9	5.0	4
9	4.4	6.3	2.3	2.4	5.2
10	1.4	2.0	9.3	8.2	5.8
Total	25.8	41.1	83.1	28.9	26.9
Plot Average	2.58	4.11	8.31	2.89	2.69

1/ Grams per .25 m plot. To convert to lbs/acre multiply by 72.7

Annual plants of the shadscale vegetation type were relatively dense in favorable microsites but in some interspace areas practically no plants were growing. Average plant height of the Bromus tectorum was 15 cm (6 inches). Average cover per .25 m plot was 116 cm^2 of 46%.

2. Sagebrush-greasewood vegetation type

Table 27. Biomass production of understory vegetation in sagebrush greasewood type (gm/plot)[2].

Replication	Location 1	2	3	4	5
1	12.8	13.4	.7	.9	5.4
2	3.9	0	.2	4.3	3.6
3	6.6	4.6	.3	3.1	0.7
4	17.7	.1	0	3.2	1.1
5	.4	0	2.9	.3	2.9
6	0	2.4	1.8	1.3	.8
7	.2	13.5	4.3	2.1	4.8
8	12.1	27.3	1	6.4	27.6
9	0.1	0	.3	.2	6.6
10	.5	0.9	.1	2.0	6.1
Total	54.3	62.2	11.6	23.7	60.3
Plot Average	5.43	6.22	1.16	2.37	6.03

Annual plants in the sagebrush greasewood vegetation type were abundant in protected micro sites. There was considerable ner growth on shrubs for this time of the growing season. Stipa comata and Oryzopsis hymenoides showed vigorous growth and excellent seed production. Bud sagebrush was making good growth and recovery from minimal growth in previous years. Average cover per .25 m^2 plot was 25 cm^2 of 10%. Signs of animal use was much less than in previous years when drought forced wildlife species to consume the bark of greasewood and spiney pads of prickly pear cactus.

3. Juniper vegetation type

As in previous years the amount of understory vegetation in the juniper type was very limited and restricted to micro sites where protection from grazing and insoluation encouraged growth of annuals. Old juniper litter, as in other years, appeared to restrict annual plant growth under the juniper canopy. Understory biomass was less than in the shadscale or the sagebrush - greasewood type (Table 28).

Table 28. Biomass production of understory vegetation in juniper vegetation type (gm/plot)1/.

	Location				
Replication	1	2	3	4	5
1	1.3	0	.2	1.2	.4
2	.3	0	.2	2.3	1.2
3	.9	3	.5	.4	.6
4		2.6	.3	.8	.7
5		3.1	.8	1.9	0
6	.9	1.4	.2	0	3.2
7	.3	.5	.9	.3	.5
8	.2	.7	1	6.9	.3
9	5	.4		0	1.0
10	1.6	7.8	2.6	.2	1.1
Total	15.0	34.5	6.7	14.0	9.0
Plot Ave.	1.5	3.45	.67	1.4	.9

Understory plants were sparse where in direct association with the juniper. Open spaces and areas under sagebrush canopy were the sites of greatest production.

Juniper trees showed signs of cold temperature damage during the very cold - open sky - days in the winter of 1978-79. Hedysarum boreale, Utah sweet vetch, was in a vigorous growing condition. Cheatgrass limited to sites in association with sagebrush. Average cover was about 25 cm^2 per 250 cm^2 plot or about 01 percent.

4. Riparian vegetation type

The riparian habitat is much more productive than the other three types that occur on the oil shale tracts (Table 29).

Table 29. Biomass production of understory vegetation in riparian type (yield in gm/plot)[4].

	Location				
Replication	1	2	3	4	5
1	8.1	72.5	20.7	0	8.7
2	10.1	14.4	12.6	.2	2.3
3	2.2	14.2	22.6	0.1	11.8
4	2.4	52.4	23.3	2.7	4.8
5	5.2	32.0	44.3	.8	
6	10.8	18.8	43.9	15.4	1.4
7	12.6		152.5	12.0	13.5
8	5.3	22.7	18.6	1.9	8.4
9	14.6	10.7	141.6	1.4	5.6
10	6	12.5	124.1	2.4	5.9
Total	77.3	250.2	603.4	36.9	62.4
Average	7.73	25.02	60.39	3.64	6.24

The year of 1979 was a good year for production of understory biomass compared with 1978. Plants were growing abundantly in the deep fertile bottom land soil of White River. Average height of the mainly grass understory was 30 cm (1 foot). The cover estimates were 10.2, 16.7 and 17.7 cm^2 for the river bottom plots as compared with 35 and 39 cm^2 in the bottom land of Evacuation Creek.

In comparison with previous years of vegetation sampling 1979 was a better than average year as seen by the biomass harvested from the various vegetation types. The riparian type is consistently the high productivity area over the five year period. Shadscale and sagebrush, greasewood are much more consistent than the juniper type in annual productivity. Clearly, 1975 was a banner year for annual species biomass because of the favorable rainfall distribution in the spring.

Table 30. Average biomass production of four vegetation types on oil shale tracts Ua, Ub. Data are in gm/m^2. No. of plots vary each year.

Year	Shadscale	Sagebrush Greasewood	Juniper	Riparian
1975[2/]	224.3	51.1	3.8	533.3
1976[2/]	3.8	20.9	.25	30.6
1977	___[1/]	___[1/]	___[1/]	20.6
1978	5.4	35.1	1.6	80.0
1979	16.5	16.9	6.3	82.5

1/ Vegetation not sampled, too meager to harvest.

2/ Data taken from Final Environmental Baseline Report.

B. Sagebrush stem growth as an index of shrub productivity.

Continued monitoring of sagebrush stem (or leader) growth provides a biologically-integrated measure of site favorability. Even though a given year may appear to have been favorable for plant growth the actual measurements tell much about the net effect of weather on plant growth. The study of sagebrush stem growth at a series of selected sites in the four compass directions from the proposed retort site should prove useful as a background index of conditions prior to actual operations. After operations begin the responses of sagebrush may be measured to determine if any impacts have been registered in the growth responses of sagebrush.

Methods followed in previous sampling years were utilized without change in 1979. The six sites previously studied were visited on October 20, 1979. On each site a transect was laid out along which 20 plants were chosen for sampling. Twenty stems were measured for each plant. Utilizing the bud-scale scars of the previous year as a base of measurement to the tip or longest leaf of current year's growth.

1. Six sites and their appearance in 1979.

a. Site 1.

This site is in Section 22 just west of the proposed retort location. Abundant growth was noted on all perennial species (Figure 12). Greasewood produced abundant seeds which has not been observed for the past 2 years. Summer weeds were plentiful in disturbed areas although interspace areas normally bare were still bare. Sagebrush stems appeared to be longer than in the past and were supporting an abundance of flowers.

Figure 12. Sagebrush sampling site No. 1, west of the proposed retort area. Abundant growth of perennial species was noted.

Figure 13. Sagebrush sampling site No. 2, east of proposed retort area. Grayia spinosa was later than usual in loosing its leaves.

b. Site 2.

This site is also in the vicinity of the proposed retort area but about one-fourth mile to the east (Figure 13). Sagebrush leader growth was vigorous and long with many flowers evident on the top of the plants. Russian thistle and halogeton plants were abundant and of a size greater than in the past 2 years. Annual grass occurrence was spotty.

c. Site 3.

This site is near the center of section 30 along the road to Asphalt Wash and is about four miles west - and upwind from the proposed retort site. As in other areas, the shrubs on this site were beginning to flower in a degree of abundance not seen for the previous 2 years (Figure 14). Stipa and indian ricegrass had grown a better than average amount in 1980 and produced numerous seed stems. Very little annual forbs and grasses were noted on this site. Halogeton was quite evident along the roadway to the north of this site.

d. Site 4.

Site four is south of the proposed industrial site by about two miles. Seed production on sagebrush, shadscale and rabbitbrush was prolific. Late summer annuals such as russian thislte, halogeton and lambsquarters plus old litter from spring biomass production were still standing but their occurrence

Figure 14. Site 3, located on road to Asphalt Wash area has an average density of sagebrush plants. Flowering of shrubs was a major difference in this plot in 1980 compared with other years - except 1976.

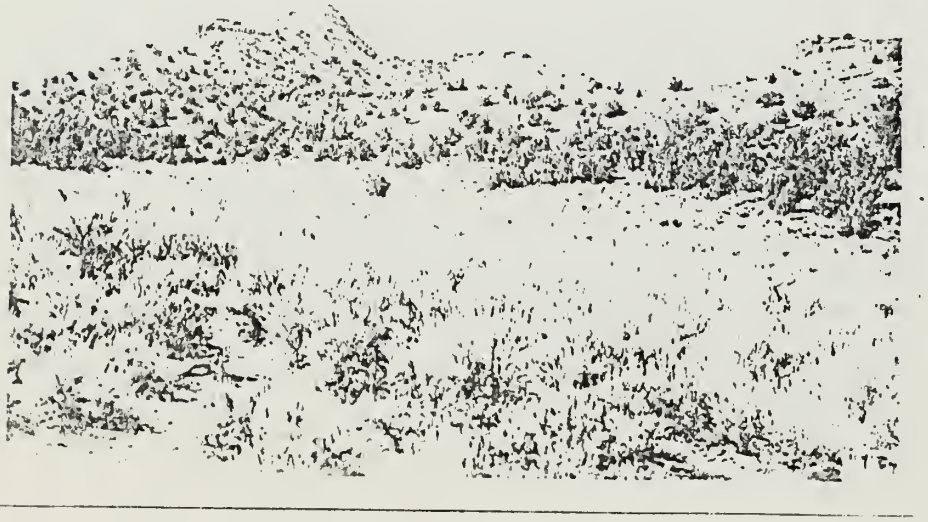


Figure 15. Site 4 is in the west center of Section 35 about 2 miles south of this proposed retort site. Plants looked to be in better than average vigor.

was spotty and limited to protected areas of more favorable soil. Sagebrush flowers were abundant and long. Grazing not as obvious as in 1978.

e. Site 5

This site is in the southeast quarter of section 15 in the shadscale vegetation type. The sagebrush plant community is located primarily on a north-facing slope (Figure 16). Seed production is abundant. Late summer annual plants, halogeton predominating, were still alive and dense in protected micro sites. Litter from spring plant growth was moderately abundant but spotty in distribution, shadscale was producing abundant seed. Area not grazed as closely as in previous years.

Figure 16. Site No.5 located in a shadscale vegetation type on the eastern edge of the prototype oil shale leases.

f. Site 6.

This site is located on the north side of the White River off the oil shale lease tracts. Sagebrush and rabbitbrush were in full bloom and appeared to be greater in flowering than for the past two years. Very limited annual plant growth, suggesting a relatively dry spring growing period. Greasewood also developing an excellent seed set. No grazing evident on the site this year as contrasted with the last 2 previous years. No photograph was taken due to the late hour of the day when the site was visited.

2. Results of stem growth measurements.

Sagebrush stem growth in 1979 reflects a moderately favorable year for biomass production. Stem length at each site was relatively uniform (Table 31) and no single site appeared to have adverse environmental conditions that caused plants to restrict growth. Average stem length varied from a low of 7.25 cm at site five on the east side of the tract to a high of 9.96 cm for site 3 on the road to Asphalt Wash. The sites in close proximity to the proposed retort area, sites land 2, had average lengths of 7.59 and 9.88 cm respectively.

The uniformity of stem length in 1979 was high and based on the standard deviations for each site, all but site five were within the standard deviation range of site 3 which had plants with the longest stems.

As the study would indicate stem length appears to be a means of assessing site conditions and the general uniformity - or lack of it among the various areas of the tracts where similar plant

Table 31. Average stem length (cm) as measured September, 1980. Data are mean values for 20 stems from individual, 1980 plants and the standard deviations of such values.

Plant No.	Site 1 Stem Length Average	SD	Site 2 Stem Length Average	SD	Site 3 Stem Length Average	SD	Site 4 Stem Length Average	SD	Site 5 Stem Length Average	SD	Site 6 Stem length Average	SD
1	6.99	1.50	8.31	2.78	10.96	2.30	9.12	2.80	7.70	1.02	8.14	2.09
2	7.97	1.17	10.08	2.77	9.95	3.36	11.50	2.69	9.14	1.48	8.11	1.55
3	9.20	1.85	16.70	7.01	7.33	1.49	9.59	1.69	7.23	1.98	7.04	2.04
4	7.16	2.80	10.20	2.74	11.04	1.86	8.99	2.23	8.34	2.15	8.29	2.19
5	6.28	2.03	7.69	2.97	9.91	2.56	7.20	1.74	8.64	1.48	6.97	2.12
6	5.89	1.70	11.46	2.88	7.87	2.43	5.97	1.39	7.06	1.26	9.10	2.53
7	11.33	4.08	8.52	1.68	8.94	1.78	10.65	3.74	10.14	1.98	6.89	1.24
8	9.15	1.78	4.89	1.30	7.94	1.59	7.42	2.32	8.29	2.25	7.03	1.49
9	9.66	3.49	7.24	2.81	11.11	3.51	7.85	1.19	7.76	1.48	6.97	1.67
10	7.66	1.51	7.61	2.41	14.73	4.75	6.64	2.11	8.73	1.89	5.56	1.17
11	9.43	2.49	10.81	3.23	11.33	2.19	6.48	1.62	5.22	1.65	7.64	1.87
12	8.81	1.96	9.98	2.37	8.56	2.06	9.87	2.62	7.14	2.57	11.31	2.58
13	3.50	0.83	15.95	3.59	12.22	2.88	9.27	2.20	6.90	1.81	7.66	1.35
14	5.80	1.45	7.52	1.53	8.96	2.40	8.29	2.38	4.95	1.98	7.39	1.74
15	5.54	1.52	9.20	2.66	8.91	2.27	6.64	1.83	6.71	1.84	6.39	2.13
16	5.49	1.89	10.91	2.01	9.93	2.36	7.00	1.39	5.17	1.00	7.51	1.74
17	8.47	2.23	11.69	2.32	9.32	1.80	6.82	1.95	5.40	1.94	9.28	2.14
18	7.44	2.27	12.42	2.93	11.02	2.81	7.91	2.21	7.84	2.03	6.40	1.53
19	8.00	1.78	9.62	1.63	7.92	2.15	9.52	2.10	5.26	1.31	7.23	2.04
20	9.55	1.87	7.92	1.52	12.2	2.95	6.80	1.51	7.45	1.99	7.39	2.46
Total	151.74		197.71		199.29		163.44		145.05		152.34	
Average	7.49		9.88		9.96		8.17		7.25		7.67	
SD	2.00		2.73		2.47		2.08		1.75		1.88	

communities occur. As this study continues, its value increases as an index of plant/responses to weather and site conditions. Years in which erratic weather conditions prevail may be expected to cause unequal plant growth responses and thus remove potential industrial activity as a sole cause of such responses. On the other hand, when high uniformity is observed among the various sites in years prior to development this may be used as an index from which to measure any departure. As continued yearly measurements accrue it will be possible to determine the average response that may be expected of the sagebrush plants.

3. Comparison of stem growth in 1979 with previous years.

The year-to-year variation in stem growth is of considerable interest to evaluate the responsiveness of this plant characteristic to general productivity and site conditions. Growth response in 1979 was greater than any of the previous four years (Table 32). Other good years for stem growth were 1978 and 1975. Plants in site three have consistently shown the longest stem growth over the five year period of monitoring. While the shortest stems measured have generally been in site 5 and site 6.

Observations of flowering and other plant growth-development characteristics in 1979 support the relatively favorable measurements of stem growth. The abundant flowers and seeds observed in September have not been observed in previous years. Summer and fall precipitation amounts were a major factor in the improved growth environment. Even in 1975, the most favorable year of plant growth observed on the tracts, sagebrush stem growth was not as long as in 1979. The difference being in the favorable 2-week spacing of rain in the spring of 1975 but drier conditions in the late summer and fall than in 1979.

Table 32. A comparison of sagebrush stem growth in 1979, 1978, 1977, 1976 and 1975 at six sites on oil shale prototype lease tracts Ua and Ub.[1/]

Site of Measurement		1975		1976		1977		1978		1979	
Site No.	Description	Mean Stem Length	SD	Mean Stem Length	SD	Mean Stem Length	SD	Mean Stem Length	SD	Mean Stem Length	SD
1	Industrial area west Sect. 22	7.4	2.14	6.2	1.04	2.1	.35	8.4	1.76	7.6	2.0
2	Industrial area east, Sect. 22	6.9	1.12	6.16	1.63	2.0	.25	8.1	2.88	9.9	2.23
3	Section 29 west on Asphalt Wash Road	9.7	1.86	7.0	.88	4.0	1.02	10.1	2.16	9.9	2.47
4	Section 35. South of tracts	5.6	1.03	5.5	1.06	2.2	.25	6.4	1.10	8.2	2.08
5	Section 18. 3 miles east	7.2	1.31	5.4	1.17	2.8	.59	5.6	1.59	7.3	1.75
6	Section 3. North of Industrial area	6.4	1.5	4.8	1.08	2.8	.56	6.5	2.52	7.7	1.88
	Overall average	7.0		5.9		2.7		7.5		8.4	

1/ Each value is the mean length of 20 stems on 20 plants for a total of 400 observations per site in any given year.

Plans have been discussed with the wildlife biologists to integrate the plant growth data with small animal populations estimates and make some interpretations as to the effects of large biomass production in the spring versus perennial plant (shrubs primarily) growth in the summer and fall.

The plant growth information produced becomes increasingly valuable as background information for industrial site development to provide an index of yearly natural variation in plant growth.

VI. ENDANGERED SPECIES SURVEY

In July 1979, Professor Arthur Holmgren, Emeritus Taxonomist of the Intermountain Herbarium made a detailed survey of the entire Southam Canyon Area on tract Ub. Professor Holmgren did not find any endangered species in this area. His letter of report is provided as a reference for this study. Species collected on this survey were entered in the Intermountain Herbarium.

VII. PUBLICATIONS IN 1979

Interest in research on problems of oil shale development heightened in 1979 after a period of relative quiescence. We have been earnestly trying to prepare manuscripts from data contained in our 6-months and final report last January 1979. Publications and presentations plus manuscripts in the draft stage are as follows:

A. Papers presented in 1979.

Response of Atriplex canescens to potassium fertilization, soil moisture and salinity of processed oil shale. At Society for Range Management meeting Casper, Wyoming. Feb. 1979. By Steven G. Richardson and C. M. McKell.

B. Manuscripts published in 1979.

Alvarez-Cordero, Eduardo and C.M. McKell. 1979. Vegetative propagation of big sagebrush (Artemisia tridentata) J. Range Manage. 32.

Van Epps, Gordon A. and Cyrus M. McKell. 1979. Major criteria and procedures for selecting and establishing range shrubs in rehabilitation of disturbed lands. Proc. 1st International Rangeland Congress. p. 352-354.

Institute for Land Rehabilitation. 1979. Selection, propagation and field establishment of native plant species on disturbed arid lands. Utah Agric. Expt. Stn. Bulletin 500. 49 pp.

Barker, Jerry and C.M. McKell. 1979. Growth of seedlings and stem cuttings of two salt desert shrubs in containers prior to field planting. Reclamation Review 2:85-89.

Harthill, Michalann and C.M. McKell. 1979. Ecological stability -- is this a realistic goal for arid land rehabilitation? p 557-567 in M. Wali (ed) Ecology and coal resource development. Pergamon Press. N.Y.

McKell, C.M. and Gordon Van Epps. 1979. Vegetative rehabilitation of arid lands disturbed in the development of oil shale and coal. EPA Interagency R&D Program Report. Energy and Environment.

C. Manuscripts in preparation (in draft stage, submitted or in press).

Richardson, S.G. and C.M. McKell. Salt tolerance of two saltbush species grown in processed oil shale. Submitted for publication in the Journal of Range Management.

Richardson, S.G. and C.M. McKell. Water relations of Atriplex canescens as affected by the salinity and moisture percentage of processed oil shale. Submitted to the Agronomy Journal.

Richardson, S.G. and C.M. McKell. Growth response of two saltbush species to nitrate, ammonium and ureau nitrogen added to processed oil shale. Submitted to the Journal of Range Management.

Richardson, S.G., C.M. McKell, M.R. George and G. Gray Weathering effects on some chemical and physical properties of processed oil shale. To be submitted to the Journal of Environmental Quality.

Richardson, S.G. and C.M. McKell. Growth of some salt desert shrubs on processed and raw oil shale with various pH values to be submitted to Reclamation Review.

George, M.R., S.G. Richardson and C.M. McKell. Leaching effects on some chemical properties of Paraho retorted oil shale. To be submitted to the Journal of Environmental Quality.

George, M.R., C.M. McKell, and S.G. Richardson. The establishment of cheatgrass (Bromus tectorum L.) on spent oil shale from the Paraho process to be submitted to J. Env. Quality.

Van Epps, Gordon and C.M. McKell. Competition effects on plant establishment in disturbed arid environment.

Van Epps, Gordon and C.M. McKell. Season and method of planting native plant species in disturbed arid sites.